Concrete

Vol. 26 Detroit, March, 1925 No. 3

Principles and Performance with Better Concrete

By Harvey Whipple

Editor CONCRETE.

THERE are fundamental problems of large consequence still to be solved in relation to the use of the material concrete but the biggest problem in that connection involves no new dramatic discoveries or elaborate chemical and physical researches.

The biggest problem is to make use of knowledge now available.

If newly developed technical knowledge were at once applicable to the work whose purposes it is ultimately to serve, our design and construction progress would be very rapid. Actually we are always battling a new frontier where only a few have explored—in which the trails they blazed are none too distinct to those unaccustomed to pioneering.

The conventions of the American Concrete Institute serve annually to give us a new reckoning. The meetings in Chicago the last week of February mirrored the concrete industry enthusiastically assimilating some fundamental principles which are by no means new; busily seeking to apply to every-day work ideas of quality control in concrete making, at whose earlier announcement contractors, engineers and concrete products manufacturers shrugged their shoulders and complained of as impractical for application to the hurly-burly of the job.

That of course is the trite story of all progress. Shaken out of the complacent comfortableness of the ways and means to which we have grown familiar, by the insistence of a better way, we invariably struggle against that better way. If it really be a better way we are soon clamoring after an intimate knowledge of it.

In the address with which he opened the Institute convention, President A. E. Lindau pointed out:

> An immense fund of information has been accumulated regarding the properties of concrete, its resistance to the elements, its behavior under stress when subjected to external forces of load. By a vast amount of laboratory and field research, we have discovered many fundamental laws governing the making of a satisfactory product. To what extent is all this information being utilized? At the present time we are storing up data faster than we are making use of it. A visit to concrete jobs under construction will reveal the fact that the making of the concrete, the most important feature in concrete construction, does not generally indicate the advance that has been made in our knowledge of the matter.
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> One of our difficulties, no doubt, lies in the inertia of trade practice.
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> This particular problem, then, seems to be one of education, of continuing to spread broadcast the things that have already been learned.
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> It seems clear that one of the tasks immediately before us is to reduce our knowledge of making good concrete to its simplest terms and carry that message to the man in the office as well as to the man on the job.
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> In line with our campaign of education, a very promising step has been taken in the matter of field control of concrete. Although considerable work has been done in this direction, the subject is new and the technique is undeveloped. At this moment it would be rash to predict how far these new methods will carry us toward the goal of better concrete. They do, however, carry the results of our research directly to the job and stimulate interest in obtaining a quality product.

It is fortunate for the industry that the objects of the American Concrete Institute are not attained in the mere discovery of fresh knowledge. Such discovery is but half the battle. The Institute is not a small body of the intellectually elect who live in the rarified atmosphere of new science. It truly *includes* the elect in the science of concreting but along with them a considerable company of earnest workers seeking to apply this fresh product of research—smoothly, economically and with a minimum of stoppage of the machinery of production—to the undramatic, work-a-day requirements of the job.

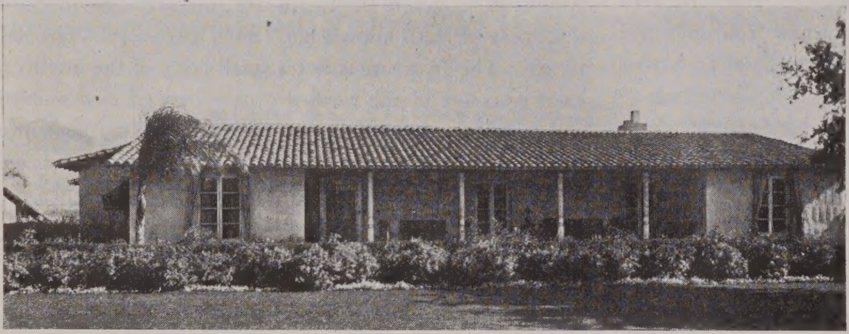
So we find in the Institute little of the high-and-mightiness and the too lofty professionalism supposed to be characteristic of the realms of theory and research. Instead there is a cosmopolitan recognition of the organization's double purpose—first the discovery of knowledge, and second, its dissemination and application. The real test of the first is the practical success of the second.

Knowledge of the hows and whys of better concrete is only half acquired until it is put in such form that "Bill" the mixer man, has absorbed it in terms which he can meet with the tools and the raw materials at his disposal. The job is the thing.

Buildings, bridges, sewers, dams—these are the things for which civilization halts. As sieves and test tubes aid us to supply them, so the laboratory has helped. No other test matters than this—*will it work?* As it is a duty upon one side to discover so it follows that the discovery must be applied. As the two human elements involved in this duality of progress come together upon the practicability of ways and means, real progress is recorded. In this joining of theory with practice, of principles with performance there lie the real adventures of an industry in which we are encouraged by so much progress and lured by high achievements, just around the corner.

Examples of Heavy Double Wall Concrete Construction

Two views of the Flintridge Cottage, Myron Hunt, Architect



The Flintridge Country Club

Thick, Double Wall Concrete Construction in California

By Myron Hunt

ARCHITECT, LOS ANGELES, CALIF.

In Southern California and in Arizona there is developing a type of construction which may well become one of the standard types in common use in this district where wood is scarce, and cement and concrete aggregate are less so. It is commonly called "hollow concrete wall" work. It represents a practical means of obtaining a hollow monolithic wall at a reasonable price.

Something over a million dollars has been spent in this office alone on this type of construction within the last three or four years, including first, a golf club, then a number of minor residences, later, four small hospitals, one of them running into over a quarter of a million dollars, however, and the last completed project is some sixteen bungalows for the San Marcos Hotel, Chandler, Arizona, while there are now on our boards two institutions, one a home for retired ministers, that will comprise perhaps twenty or thirty buildings, and the other, an orphanage to take care of 125 children.

Senator Frank P. Flint was the financial backer of the Flintridge Country Club. He wanted to make it look like an old mission building. This meant thick walls. Adobe was out of the question. It had proved expensive and impractable in the long run. When the commission for the building was given to us, he reported having heard of a man, James Johnson, who had a method of casting a hollow wall. We went into the matter with Mr. Johnson and discovered what seemed to be a meritorious type of construction and adopted it.

Mr. Johnson's method is patented. The patent is dependdent upon a flexible metal form, composed of two end pieces collapsed by the use of a lever, with two side pieces which fall into the void when the ends are thus collapsed. The general scheme is illustrated on the sheet of typical details published herewith.

The building we started to put up was nearly 500 ft. long, one story, on sandy soil, in a country where it never freezes and the pavements and the porches could be directly on the ground and at the ground level, southern fashion. The walls were built to show 32 in. thick. The outside web was 4 in., the inside the same, leaving a 22-in. void. These voids were anywhere from 3 to 4 ft. long, and forms were on hand for shorter voids when necessary.

This meant a very considerable foundation. It looked as though we were going to waste all the money on the foundation that we thought we were going to save above, so we adopted the same or a similar method of construction in building the foundations.

Then, we realized that we were going to have to heat the building with steam for a month or two in the winter and that we would have to have tunnels beneath the concrete and terrazzo floor which rested directly on the ground, and we developed the idea of turning the hollow foundation walls into tunnels.

These tunnels were built as indicated by the first footing section on the typical detail sheet herewith. A trench was dug, 12 in. of concrete was cast at the bottom of it, 6-in. walls brought up to the level of the under side of the floor, hangers placed across the tops of these walls to carry the steam and hot water pipes, which were not even covered. Metal lath was placed against the opening on light rods, then this lath was buttered with a little cement mortar and the rough floor cast right across the building and over this metal lath permanent form, which did not have to be removed.

It is desired to have a terrazzo floor throughout the building. There were not many partitions, and we conceived the notion of putting down the terrazzo in advance of the partitions, or even in advance of the exterior wall going up, grinding it down to within 10% of the final polish. This saved money because it eliminated a lot of hand work along the walls and turned out satisfactorily. After this, the walls went up, the cross walls were made of the same materials as the exterior walls. A wooden roof was put on with tile.

The specifications called for plastering the exterior and interior. The forms for the exterior of the walls, that is to say, for the outside of the walls, were sheets of metal standardized to 2½ ft. high and from 4 ft to 6 ft. long, turned over a light frame. Two holes were bored through the frame, a ¼-in. rod run through these holes and as the casting was done 2 ft. 6 in. each day, the same forms were taken off and re-used, the form of the new day resting on the ¼-in. rod. which in turn rested on the previous day's casting.

The metal was inclined to buckle. An evidence of this may be seen in the detailed picture of the Flintridge Cottage. It produced rather an interesting surface. As soon as the metal of the exterior forms got a little rusty, some of the cement stuck to it. It was found that the pitted surface that resulted in the casting was so interesting in the strong southern sunlight that it was determined to do away with the plaster job that was specified, and only touch up bad places. This work of touching up was done by a high class laborer, who when he got through, put a cement wash over the green wall and that was the end of the exterior. This proved so successful that we used the same methods on the interior of this particular building. Of other more finished buildings, some have been plastered on the outside, all have been plastered on the inside.

Winter came and everyone was dumbfounded to find out how little oil was being used in the boiler room at the Flintridge Country Club. It transpired that the hollow walls acted like a thermos bottle and held the heat, which was a gratifying result.

Summer followed. The site of the building was in a place exposed to the sun and at the edge of a valley overlooking a dry wash which was notoriously hot. The building on hot days proved to be the coolest place in the neighborhood, so cool that players when they came in could often put on their sweater vests. Again, the hollow walls, with their confined air space, were acting as insulators. The building was a great big thermos bottle.

In the meantime, Mr. Johnson had been building a number of minor buildings for other people. This office tried out the construction of a residence or two, and finally built one two-story residence, which has all the qualities described for the Club above.

About this time a hospital problem for a small inland community came to the office and the notion of making it a one-story hospital, using this type of construction, was suggested to the Committee. They were convinced that it would be too hot. An arrangement was made with them to pick out the hottest day they could find, telephone the office and we would give them a lunch at the Flintridge Country Club. The result is the San Antonio Community Hospital at Upland, recently completed, and as warm in winter as it is cool in summer.

The success was so great that there followed the Riverside Community Hospital, Pasadena City Isolation Hospital, and a little Preventorium in Altadena, all using a similar method of construction.

Other contractors became interested in producing similar walls. Mr. Johnson's method of obtaining his voids was patented. They evolved collapsible forms, two of the most successful of which are illustrated in the accompanying cut. Now there are half a dozen men all doing equally good work, and each with his own pet collapsible form. Even Mr. Johnson's form has been modified and improved, either by himself or by people to whom he has sold royalty rights.

The next problem put up to us was by people who manufactured Stone tile block, being a brick variously 6x12x4 and 8x12x4, each brick having two holes cast through it, and the tiles cast by a wet process. It has always been against the policy of this office to use dry pressed concrete block because it is too much like hard work to make certain that they are sufficiently wet when set not to have the mortar joints robbed of dampness during setting by the suction of the block.

At the request of a contractor who wanted to substitute this material for the hollow wall construction, we made a typical alternate, showing how the walls of this building, which were 20 in. thick, could be built, using a standard 6-in. block except where a web was wanted, when they had to intersperse a few 8-in. block. This 20-in wall gave us an 8-in. air space with additional air spaces within the block themselves. The cement block people, including the cost of plastering the exterior of the building with a particularly good job, beat the hollow wall people, in this instance, and produced a thoroughly substantial result.

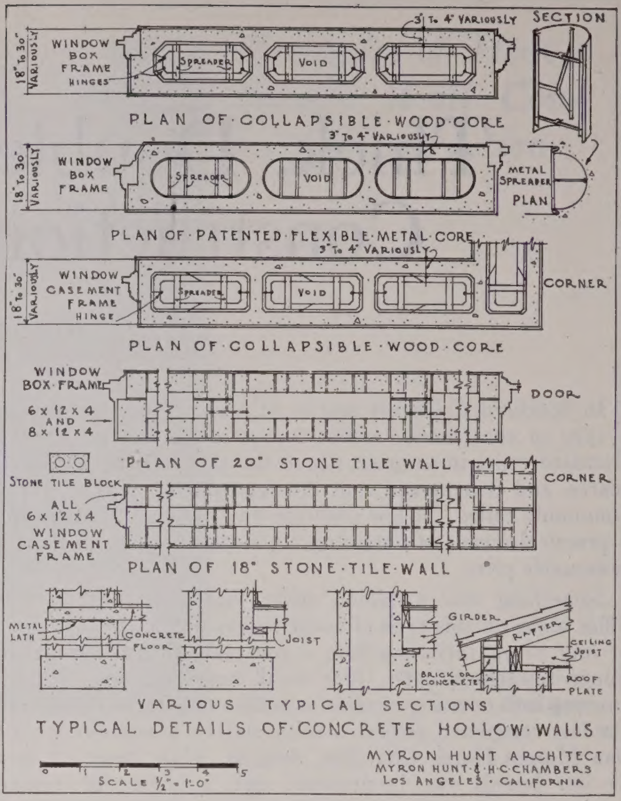
In the case of the hollow block construction, reinforced concrete band courses were cast at the joist levels and at the roof level. In all the constructions, of course reinforced concrete lintels were used over doors. This is not wholly true, however. Wherever possible, windows were brought up near enough to the top of a low wall to make it unnecessary to have a concrete lintel. This filling in with a metal lath and plaster lintel took up the shrinkage.

One of the troubles with the construction is expansion and contraction, where buildings get as large as some of these buildings are. Definite expansion joints, definitely admitted on the interior and exterior, with a V-shaped surface and with a locked intersection at the center, are provided sufficiently to eliminate the vertical cracks resulting from horizontal shrinkage of these long walls.

One client plastered these up with a result that can be imagined. The crack looks worse than if it had been omitted, because the walls will come and go with weather.

In the City of Los Angeles, light reinforcing is required in these walls under the ordinance. Speaking generally, where the walls are 20-in. thick and over, and where there is no law requiring reinforcement and the building is only one story high, this reinforcement is not used, and its only advantage could be its possible use as temperature steel.

This construction cannot hope to compete with 2x4 studs. It cannot even compete with 6-in. burned clay exterior walls. It can compete with brick veneering or hollow burned clay veneering. One of these residences was figured in competition with a hollow burned clay job, plastered on the exterior, 20-in. walls, 6-in. inside, 6-in. outside, with a 6-in. void, with approximately 1 in. allowed for plaster inside and out, against this method, and the saving was the difference between $19,000 and $21,000 in favor of the concrete. The contractor didn't make much money on the job so probably the saving should have been little or nothing.



TYPICAL DETAILS OF CONCRETE HOLLOW WALLS

MYRON HUNT ARCHITECT
MYRON HUNT & H C CHAMBERS
LOS ANGELES · CALIFORNIA

Buildings of this type, in proportion to their degree of elaborateness and size, but all with tile roofs, have been put up, ranging all the way from $4 to $6 per sq. ft., which again places the construction where it can be used for comparison.

We find that the only type of standard stud and metal lath construction which we would be willing to put out of our office is just as expensive as this construction.

One additional statement should be made. We have tried making 12-in. walls and find they are inclined to be damp.* The success of the construction results from the fact that any dampness that penetrates the outer wall is evaporated before it can go through the webs by reason of the large size of the void. When, however, the void is cut down to 4 in. to 6 in., this is not the case, and, incidentally, the insulation is not as good. We have therefore set a minimum standard of an 18-in. wall, and as stated above, have built them as thick as 30 in. where the size of the building and the character of the design made it desirable and worth while.

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*They should not be, when well built—hundreds of double wall jobs are giving entire satisfaction under more difficult climatic conditions.—Editor.

It is possible in this magazine to give but a very small fraction of the information developed by the convention of the American Concrete Institute. While a few other papers and reports will have attention in succeeding issues, to the extent of abstracts or excerpts, a complete record of the convention—papers, reports, and discussions—will appear in the Institute Proceedings, *Vol. 21, 1925.*

The American Concrete Institute Convention

The uppermost thought in the American Concrete Institute Convention at the Drake Hotel, Chicago, February 24 to 27, inclusive, was that of ways and means and results in applying on the job, our newer theories of the quality control of concrete.

The convention sessions were in themselves an interesting commentary on criticism from the field two and three years ago when certain of the tentative suggestions of the Joint Committee on Concrete and Reinforced Concrete, presupposed such intelligent design of a concrete mix that its 28-day strength might be foretold approximately before the "mud" left the mixer.

In this interim enough engineers have learned how to do it so that a reform may already be said to have been launched safely and the horizon of the concrete designer appreciably extended.

Nor is the constructor, on work in the field, alone—the concrete products manufacturer is close behind him with conditions for quality control application which give him a big advantage for factory work.

Of outstanding interest were several convention sessions.

First, railroad men testified to the practicability and economy of field control methods.

Second, a miscellany of papers was presented on the possibility of discovering the underlying causes of crazing, the value of certain color and other chemical admixtures in concrete, quality control on the Purdue stadium, and a cross-examination of Mr. Cement to determine his complicity in the crimes and misdemeanors of concrete.

Third, two sessions for concrete products manufacturers, intended primarily to create a basis for more general adoption of correct and economical mixes.

Fourth, a session given up to a symposium on form work for concrete building construction.

Fifth, discussion of building regulations now in process of development, based upon the recent revised report of the Joint Committee on Concrete and Reinforced Concrete.

The registration at the Convention was about 425. There were 18 committee reports and 20 papers on the program, divided among three afternoon sessions, three morning sessions and three evening sessions, two of these last being concurrent—the whole covering a four-day period which also included a banquet. Banquets are things which not one man in ten wants to attend—but in some cases is not sorry in the experience itself. The banquet committee, feeling that a four day diet of concrete is trying, arranged an evening which was nothing short of a success. Frank Wight, Editor *Engineering News-Record*, was a brilliant toastmaster with an appreciation of the novel and the dramatic. James Weber Linn, professor of English, University of Chicago, and editorial writer on the Chicago *Herald Examiner* took his audience away from the crass and the calculating, away from literalism and standardization, to some conception of the social value of dreams, convincingly lauding the dreamer as the real pioneer in all the progress of civilization. Prof. F. R. Moulton, astronomer de luxe, also from the University of Chicago, took his elated listeners on a trip to the stars where mileage units are in twelve figures.

A pleasant banquet feature of the banquet program is the presentation of the Wason medal, this year to Richard L. Humphrey, the Institute's president in its first ten struggling and formative years, for his papers—a review and a prophecy presented at the 20th anniversary meeting in 1924.

The Institute, as an organization, was able to report for itself a substantial growth—from a little more than four hundred in 1920 to more than 1500 at the opening of the Convention—the greatest increase attained in the convention year just ended.

A. E. Lindau, Chicago, was reelected president; E. D. Boyer, New York, vice president; Harvey Whipple, Detroit, secretary and treasurer. S. C. Hollister, Philadelphia, John J. Earley, Washington, and Duff A. Abrams, Chicago, were also reelected directors.

It is impossible in one issue of this magazine, and that so closely following the convention, to report more than a few of the many high spots in a program which was notable in its recognition of the lively spread of interest among engineers, contractors and concrete products manufacturers, in the technical elements of modern concreting.

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The Railroads Adopt Progressive Concreting Methods

The first session of the convention the afternoon of February 24, while devoted to problems of particular interest to railroad engineers, had a direct bearing upon concrete work in the field, whether railroad structures or not. There were four papers following President Lindau's opening address. C. P. Richardson, engineer of track elevation, Chicago Rock Island & Pacific Ry., Chicago, presented the first, entitled, "Theory Must Aid Practice in Concrete Making." The other papers were: "The Design of Concrete Mixtures under Field Conditions" by T. P. Watson, assistant engineer, Pennsylvania R. R., Pittsburgh, Pa.; "Field Control of Concrete on the Delaware River Bridge," by A. W. Munsell, assistant engineer, Delaware River Bridge Joint Commission, Philadelphia, Pa.; "Notes on Laitance," by R. M. Miller, formerly resident engineer, Virginia Terminal Ry., Sewall Point, Va.

Mr. Richardson's paper was a proper prologue to the session. It served to remind engineers that the newer theories of good concrete are not altogether strange, that they replace many rule-of-thumb practices which have for a long time been a guide to the use of suitable materials in the right mixes.

In discussing Mr. Richardson's paper, which will be abstracted in a subsequent issue of CONCRETE, the fact was cited that the large number of comparatively small jobs in railroad construction work made the carrying out of specifications more difficult, although accomplishing results leading to better concrete on the large jobs will also lead to better concrete on the small jobs representative of work in other lines as well as in railroad work.

Mr. Watson's paper related experience in field control of concrete placed in the construction of the Beck's Run bridge near Pittsburgh, Pa. A forceful thing in the presentation of his paper was Mr. Watson's frank statement of his use of Abrams' theories. Mr. Farnham, Watson's chief, asked that these quality control theories be used on this bridge job.

Watson thought he knew concrete better than Abrams, so Farnham said the control theories should be thoroughly tried out to prove Abrams wrong. It was on that basis the work was undertaken and nobody is more thoroughly sold on the idea in the process than Watson. Mr. Watson's paper included examples of actual computations to produce desired strengths of concrete and these will be presented in a later issue of this magazine. Gratifying results were obtained with this concrete and observations indicated the desirability of a standard practice for carrying out field tests.

There was no bridging of concrete around the reinforcing rods and no honeycombing in any of the 65 girders in the structure. In filling forms around numerous reinforcing rods, mortar was discharged first and as the concrete was deposited, its weight pushed the mortar ahead and into the spaces around the rods. The opinion was expressed by the author of the paper that square twisted rods as used on the Beck's Run bridge were considered the best as the twisting removes the shop scale and is the best test of the quality of the steel.

A. W. Munsell's paper on the field control of concrete on the Delaware River bridge anchorage will be abstracted in a later issue of CONCRETE, with particular attention to the conclusions drawn by the author as a result of his observations.

In discussing Mr. Miller's paper on laitance, an abstract of which appears elsewhere in this issue, the question was raised as to whether or not there would be laitance present if the concrete mix is properly designed. The amount of laitance was found to increase with the amount of water in the mix. The alkali content of the cement was also cited as being an important factor in the formation of laitance.

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Demonstration for Products Manufacturers

Two coordinate sessions were held on Tuesday evening Feb. 24. One, including a demonstration by Stanton Walker, J. W. Lowell, C. L. Bourne and J. W. Kelley, to show the products manufacturers the application of practical methods of determining economical proportions of aggregates in the making of concrete building units. The other section was taken up with a symposium on forms for concrete work and the question box consisting of brief discussions of a number of questions on concrete construction.

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Forms for Reinforced Concrete Building Construction

Three papers by members of committee C-4 on Forms for Reinforced Concrete Building Construction, included: "Column and Floor Forms—Examples of Framing and Releasing," by J. A. Turner, Turner Construction Co., Philadelphia; "Column Forms," by L. H. Usilton, general superintendent, Barney-Ahlers Construction Co., New York; "Adjustable Shore Forms vs. 4x4 Wood Shores," by E. C. Harding, general superintendent, Ferro Concrete Construction Co., Cincinnati, Ohio. They form an important record of practice in this rather unstandardized department of construction. Discussion of this symposium brought out that the keynote in the construction of forms for reinforced concrete buildings is regularity and simplicity. The design and construction of the forms comprise one of the most important factors in building work, the labor cost on forms being given as about one third of the cost of a building. On certain jobs cited, 70% of the total labor cost was for the forms.

On four out of five of the low cost jobs referred to by E. C. Harding, adjustable shores were used. No broad statement could be made as to the relative value of adjustable shores or 4x4 shores because of the dependence for their economy upon governing conditions. With 4x4 shoring, wedges are depended upon, and with adjustable pipe shores the jacking device is utilized to hold the form to the proper elevation and carry the load. Adjustable form shores were found to require more care in handling than the 4x4 wood shores.

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Destructive Agents and Protective Treatments

Under the heading "Destructive Agents and Protective Treatments," F. R. McMillian, Secretary of Committee E-6, presented an abstract of its preprinted report of studies of structures which have undergone severe climatic conditions for from 10 to 20 years—some entirely sound, others showing ravelling or other defects. One structure showed a few patches of good concrete on the surface. It was of cylcopean masonry with thin layers of very wet mixed concrete which showed streaks of disintegration at the various levels to which it was originally placed. The aggregates were good and are believed not to have contributed to the disintegration of the structure.

The second case illustrated was that of a dam built about the same time, using practically the same mix with slightly different materials. Concrete was placed under a better arrangement with rigid control of the consistency and a dryer mix.

Another structure referred to showed effloresence or incrustation on the surface probably due to the fact that a few batches were placed too wet. The committee's investigations led to the conclusion that excess water in the mix is a fruitful cause of porous concrete allowing the penetration of water into or through the concrete, with possible destructive frost action. The presence of laitance is considered evidence of over-wet mix and the removal of the laitance does not remove the porous concrete.

The following causes of porous concrete are cited by the committee, based upon the structures studied.

1—Excess of mixing water,

2—Deficiency in cement,

3—Dirt or excess of fine material in the aggregate,

4—Segregation of materials in handling and placing the concrete.

Of these causes the first is most important and the others become more important because of an excess of mixing water, except in the case of number 2.

The general conclusion drawn by the committee is in part as follows:

> The work of this committee in the study of faulty concrete is one of several efforts now being put forth by different agencies in response to a growing deamnd for an answer to the question: "What is wrong with concrete?" It needs but a little familiarity with the discussion of the past few years to realize the extent to which the search for an answer to this question had led in the direction of some involved or mysterious explanation. The committee does not decry such search nor indeed any search that will add to our knowledge of concrete. But is it not possible that in the search through the realms of mystery, an obvious answer has been overlooked? The committee believes, at least so far as a great majority of structures is concerned, that the production of permanent structures can be accomplished through the simple expedient of producing concrete that is impervious to moisture.
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> This leads to the second conclusion which the committee has drawn from this study, namely, durable concrete, that is, impervious concrete, involves no mystery. The requirements are:
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> *Clean aggregates of durable minerals; a mixture of a fair degree of richness; the use of a puddling consistency; and care in placing and curing.*
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> A number of methods for the design of concrete mixtures have been developed within the past few years which differ somewhat in their method of approach to the problem and in the details of manipulation. This diversity in the methods proposed by recognized authorities has served to confuse many engineers, whose interests and responsi-

bilities in other phases of engineering and construction, as well as limitations of laboratory equipment, have not permitted them to make their own investigations. As a result of this confusion attention has been diverted from the outstanding importance of durability by the emphasis which has been placed on strength and economy in these theories of proportioning. Of course, these factors must not be neglected, but they should not be allowed to obscure the fact that the life of the structure is also an element of ultimate cost, which, in most engineering works, outweighs many times the economies possible by fine distinctions in theories of proportioning. The old rule which requires the use of an amount of cement somewhat in excess of the voids in the aggregate is a good rule when combined with the newer knowledge—that no more water should be used in mixing than necessary to produce a workable puddling consistency.

In discussing the foregoing report C. A. P. Turner pointed out that an aggregate must be selected which is not affected by frost. Prof. W. K. Hatt, referred to the oolitic limestones as being satisfactory for concrete aggregate but pointed out that some of the bastard limestones found with the oolitic limestones in certain beds were not satisfactory. The use of these poorer stones as aggregate contributed to the disintegration of the concrete in which they were placed.

In referring to the use of gunite for repairing concrete structures where disintegration was taking place, John V. Schaeffer, pointed out that the water content of gunite is regulated automatically to 3 or 3½ gallons of water per sack of cement. If the gunite will stick, it is of the proper density, but if too much water is used, the gunite will sag and if not enough water is used, it wall not stick in place.

Nathan C. Johnson, referring to cleavage planes and rise in concrete, stated that based upon one-half mile of core boring, a rise of excessively fine material of 12% was found to be the average in puddled concrete. The aggregate must be adjusted to the size of the work in which it is being used if impervious concrete is to be produced. As the cement used in concrete consists of calcium, silica, and alumina, the aggregates containing these materials in the concrete may so damage the cement that the effect will be the same as if the cement had not been properly compounded at the mill.

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Aggregates

A brief progress report of Committee E-5 on Aggregates, bears on the report of the Joint Committee on Concrete and Reinforced Concrete. In connection with the use of blast furnace slag as an aggregate, it was suggested that the weight of the slag should be not less than 70 lbs. per cu. ft. where the concrete is to withstand abrasion and all blast furnace slag should be free from iron shot. The possible use of slag from copper and other non-ferrous metals was suggested.

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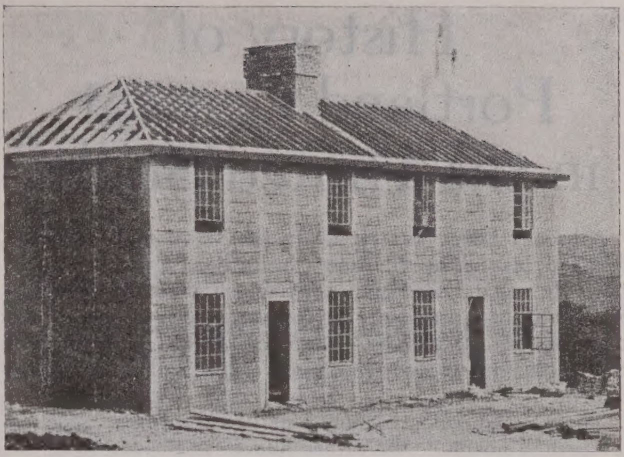
Building Design and Specifications

S. C. Hollister, chairman of Committee J-1, the Institute's representation on the Joint Committee on Standard Specifications for Concrete and Reinforced Concrete, submitted that the Joint Committee report was not discussable at this time, but should be received as a tentative specification for two years consideration, and published in the Institute's *Proceedings*. The committee will welcome discussion and recommendations for changes, to be submitted in writing.

F. R. McMillan presented a report in abstract of Committee E-1 on preliminary studies for revised standard building regulations. The Joint Committee report is being studied by the committee as to its adaptability to building codes. The essential points wherein the report differs from the Joint Committee report were pointed out. The maximum size of course aggregate allowed is specified as 1/5 of the form opening and for reinforced members, ¾ the clear distance between reinforcing rods. The use of air cooled blast furnace slag as an aggregate is permitted.

(Continued on page 105)



Sample Duo-slab houses before outer surface treatment is applied. Courtesy Concrete and Constructional Engineering

Duo-Slab Cottage Construction

The Duo-Slab system for house construction, developed in England, has very little in common with the better known methods of concrete wall construction most of which are either forms of monolithic construction or, by use of concrete block, follow the principles of brick work. The Duo system is essentially a system for mass production of houses on a unit basis although the unit can be made to suit any design. Its cheapness depends largely upon mass production, but it is possible to build a large number of houses keeping the same unit of construction without monotony.

The houses may be finished with any of the ordinary or desired methods.

The wall is formed of precast slabs laid on edge, one above another with a vertical space between adjoining tiers of slabs which is filled with concrete poured in situ, this binding these slabs together at their ends. The slabs may be made any desired size and are usually 3 in. thick by 8 in. high. The piers measure 8 in. across the face of the wall and are generally spaced 4 ft. on centers. The slabs are formed of a concrete consisting of 5 parts of hard clinker, 1 part of sand and 1 part portland cement.

The slabs are poured in molds each consisting of a wooden frame hinged at three corners and having fastenings at the other corner. The mold encloses a rectangular area a little deeper than the thickness of the slab so as to allow for consolidating the concrete. The area enclosed by the mold is the length of the slab and sufficiently wide to enable 3 slabs to be formed, face up, side by side, and separated by longitudinal runners or division plates.

In erecting a house, the walls are formed of two leaves with a 2-in. space between. Slabs are placed on edge, one above the other without horizontal mortar joints. As the slabs are laid, forms are built to enclose the spaces on the outer face of the two leaves and between the slabs, and concrete poured forming solid piers throughout the height of the wall, on 4-ft. centers. A patent system is used in the construction of the piers. The uprights of the framework are locked in a plumb position by transverse loops and adjustable screws shaft extending through the upright.

When the concrete which forms the pier has set sufficiently to permit the removal of the upright, another set of slabs is placed, the formwork raised, and the operation of forming the piers is continued till all is carried to the required height.

This system has been patented by William Airey and Son, Ltd. of Leeds, England.

History of Portland Cement in the United States

A bronze tablet was set up in the Town Hall at Leeds, England, last fall by the American Portland Cement Association. It was unveiled with a fitting centennial ceremony by F. W. Kelley, president, in company of members of the organization and puts at least a semi-official sanction upon the record that Joseph Aspdin was the inventor of portland cement.[1]

There is something in human nature that often neglects a division of honors. We rather like to single out some one man—a Nelson or a John Paul Jones—a Watt or an Edison—a Darwin or a Burbank. So having it virtually settled that Joseph Aspdin was the man to whose memory the bronze tablet should be cast, we can now review the whole matter in Robert W. Lesley's new book.[2] For while Mr. Lesley tells the story this side the Atlantic, our own domestic progress is so interwoven with the earlier and parallel developments abroad that the history necessarily is of an international character.

The idea which at once comes to the reader is this: While Joseph Aspdin took out a patent in 1824 and "named the child Portland," cement, as we know it, and even as Aspdin himself knew it, is very far from being a one-man achievement.

The urge of necessity, a little groping science, a great deal of hard labor, not a little of the mere casualness of happenchance—all these with many wills and many minds and untold perseverance, along unillumined pathways of chemistry and mechanics, gave us an industry. Through it all no one man's name is written much more boldly than a dozen others.

And it is by this faculty of peopling his pages; of recognizing the humor, the almost laughable happy "accidents," quite as much as the well thought plans and the hard work and the upsetting disappointments, that Mr. Lesley has made a book that is readable while instructive.

Mr. Lesley begins at the beginning with "Cements and Their Definitions" and then launches at once "Among the Pioneers in Natural Cement" and merges at that rather-hard-to-discover boundary into the "Discovery of Portland Cement." Both these chapters shuttle to and fro over the Atlantic and throw new light upon the pioneering days and we are then led through the interesting periods and phases of cement development in America—the false starts, the successes, the corporate groupings of manufacturers and the perfection of processes and of marketing methods and expansion. There are chapters on the leading pioneer companies, how high costs compelled the use of American ingenuity to the utmost; the mechanical side of the development; the commercial struggle in attaining a position of confidence in the American product; the scientific progress; the day of the promoters; lower costs; big and constantly increasing production.

Through it all is Mr. Lesley's very intimate knowledge of the whole industrial performance. The pages all through are sprinkled with people. It is men to whom you are introduced. The industry is never, in the author's hands, an inanimate monster. It is molded by scores of personalities—so you are made to feel that while Joseph Aspdin "named the child," the infant had the care of many godfathers, who served it variously at many times in many different ways.

Back of Joseph Aspdin, first of all was John Smeaton and his Eddystone Lighthouse. This beacon not only lit the way for the mariners, but it illumined the whole pathway of progress toward the modern hydraulic mortar. In a chronology of the earliest pioneers, Smeaton's name is followed by Dr. Higgins, Parker, Dobbs, Vicat, Aspdin, Pasley and Frost.

While according to Henry Reid, a distinguished Civil Engineer of England, who wrote in 1877, "Aspdin persevered in bringing to our knowledge the importance and indeed, necessity of a high temperature in the kiln," Isaac Johnson maintains that "the name 'portland' is due to Mr. Joseph Aspdin when he took out a patent in 1824 but which is no more like the cement that is made today than chalk is like cheese."

Mr. Lesley writes also from his own intimate knowledge about selling portland cement in the early days—first the imported cements, then with difficulty against the inevitable prejudice of the buyer, the new and comparatively untried American product, a result which only scientific knowledge, constant production of technical papers before engineering or other similar bodies could have accomplished.

How casual and accidental are some important discoveries and developments is shown in the discovery, extent and character of the cement rock of the rich Lehigh region as a result of the Pennsylvania Geological Survey's examination of limestones to learn their quality for iron making, made at a time when the cement industry was a struggling child. And how Millen, a sidewalk builder, became a cement manufacturer because an Englishman passing Millen's yard in South Bend, Ind., saw the barrels having the labels of an English cement manufacturer for whom he had worked. He helped the Millens to find raw materials near at hand so they might make their own sidewalk cement. Saylor's discovery of the method of making portland cement out of the natural cement rocks of the Lehigh district was another happy accident, while other similar good fortune occurred in the history of the early manufacturers.

It is a book of 330 pages. It comes at the close of a century of portland cement to add the after pleasure of reminiscence to the rough and sometimes uncertain paths of industrial development. It gives a convenient record, all in a single volume, of the big and little facts of personality and of production, of merchandising and of mechanics, of chemistry and experimentation, all of which have gone to make a picturesque story of industrial progress. Mr. Lesley, with Messrs. Lober and Bartlett for collaborators—all three a part of the story—has given us a record more intimate and colorful—touched with the genial philosophy with which Time softens the most arduous and doubtful of adventures—than anyone else could have produced.

—HARVEY WHIPPLE.

Los Angeles Prefers Reinforced Concrete

A report just published by the Los Angeles City Building department covering building permits issued in 1924 indicates clearly the preponderance of reinforced concrete structural frames for tall buildings.

Of thirteen buildings ten stories or more in height for which building permits were granted in 1924, ten have reinforced concrete structural frames and only three have structural steel frames. Furthermore, the tallest of these buildings have reinforced concrete frames.

Of the ten reinforced concrete buildings, one is 10 stories high, two are 11 stories, three are 12 stories, two are 13 stories and two are 14 stories high. One of the three steel-frame buildings is 10 stories high and two are 12 stories. The permit value of the tall buildings was $6,993,000 for the ten reinforced concrete structures and $3,000,000 for the three steel-frame structures.

The total permit value of 74 class "A" reinforced concrete buildings of all heights for which permits were issued during 1924, was $18,646,287. During the same year permits were taken out for only 15 class "A" steel buildings of all heights, with a total valuation of $5,550,300.

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[1] *Concrete,* Oct. 1924, p. 127.

[2] "History of the Portland Cement Industry in the United States with Appendices Covering Progress of the Industry by Years, and an Outline of the Organization and Activities of the Portland Cement Association," written by Robert W. Lesley in cooperation with John B. Lober and George S. Bartlett—International Trade Press, Chicago.

The Effect of Some Reagents and Conditions on

The Set of Lumnite Cement

By S. L. Meyers

In the literature on high alumina cements considerable emphasis is used in warning possible users against allowing portland cement or lime to contaminate these cements as they will cause a flash set.

In covering this phase of the setting of high alumina cements, more ground was covered than was the writer's original intention, and a more or less general use of variable conditions and reagents were employed.

The cement used in these tests was furnished by the Atlas Lumnite Cement Co. Its chemical analysis and physical tests were as follows:

Silica	6.04
Alumina	39.52
Iron Oxide	12.80
Manganese	Trace
Lime	39.80
Sulfur Trioxide	0.76
Ignition Loss	1.13
Total	100.95

The high total is probably due to partly reduced iron compounds.

Setting time taken under standard conditions of testing portland cement with a Vicat needle:

Initial—5 hrs. 40 min.
Final —7 hrs. 0 min.

Neat tensile strength at 24 hours, 746 lbs.; at 7 days, 828 lbs.; at 28 days, 990 lbs. One-to-three sand tensile strength at 3 days, 400 lbs.; at 7 days, 480 lbs., at 28 days 555 lbs.

Fineness	
100 mesh sieve	99.5
200 mesh sieve	92.5
300 mesh sieve	81.0

The Vicat needle was used exclusively in these tests; first, because it is the most accurate instrument in determining sets, and second, because the Gilmore needle is not at all applicable to Lumnite cement as the hardening starts from the center and progresses outwards; the center of the test piece may be very hard while the top will not nearly show an initial with the Gilmore needle.

Owing to this peculiar property of hardening from the center outwards, it was thought that the shape of the test piece and its mass might have some influence on the setting time, but a trial of these conditions failed to show any appreciable variation in set.

Portland cement was mixed in different percentages with Lumnite cement up to 50%, previous to gauging, and the following sets obtained:

Percentage of Portland Cement	Initial Set	Final Set
None	5 hrs. 40 min.	7 hrs. 0 min.
0.1	5 hrs. 0 min.	5 hrs. 50 min.
0.2	4 hrs. 50 min.	6 hrs. 15 min.
0.5	4 hrs. 50 min.	7 hrs. 15 min.
1.0	4 hrs. 45 min.	6 hrs. 0 min.
2.0	4 hrs. 50 min.	5 hrs. 0 min.
5.0	4 hrs. 35 min.	5 hrs. 40 min.
10.0	3 hrs. 15 min.	4 hrs. 25 min.
25.0	3 hrs. 5 min.	4 hrs. 20 min.
30.0	3 hrs. 0 min.	4 hrs. 10 min.
35.0	Flash	Flash
50.0	Flash	Flash

The portland cement used here was a high lime cement, but well burned with a ratio of 2.40 and containing 1.80% of sulfur trioxide.

The results up to this point do not justify extreme caution in avoiding contamination with portland cement.

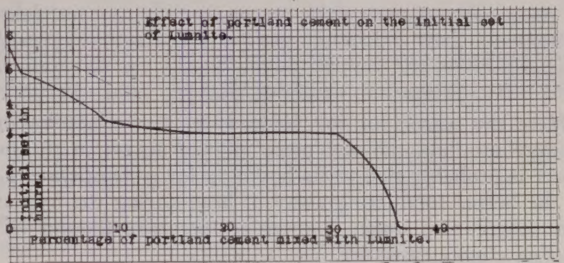


Fig. 1—Effect of portland cement on the initial set of Lumnite

Below are the results due to different external temperatures while setting:

Moist Closet Temperature	Initial Set	Final Set
35° F.	4 hrs. 20 min.	6 hrs. 45 min.
45° F.	3 hrs. 40 min.	4 hrs. 55 min.
55° F.	3 hrs. 50 min.	4 hrs. 45 min.
60° F.	4 hrs. 20 min.	5 hrs. 10 min.
70° F.	5 hrs. 40 min.	7 hrs. 0 min.
80° F.	7 hrs. 35 min.	11 hrs. 0 min.
90° F.	11 hrs. 20 min.	15 hrs. 10 min.
100° F.	6 hrs. 30 min.	7 hrs. 55 min.
110° F.	3 hrs. 55 min.	4 hrs. 20 min.

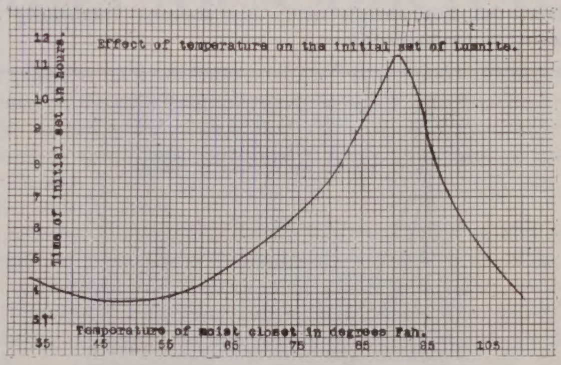


Fig. 2—Effect of temperature on initial set of Lumnite

To one used to testing portland cement these results are unexpected, to say the least, but they are no more unusual than the results obtained by varying the gauging water from 22% to 60%; in fact, one cannot predict the effect of a reagent or condition upon Lumnite merely because one knows what to expect from portland cement under similar circumstances.

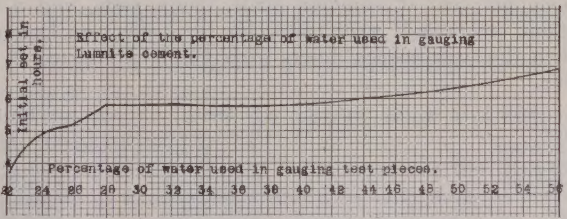


Fig. 3—Effect of the percentage of water used in gauging Lumnite cement

Effect of Varying Gauging Watfr

Percentage Water	Initial Set	Final Set
22	3 hrs. 45 min.	6 hrs. 40 min.
24	5 hrs. 0 min.	7 hrs. 0 min.
26	5 hrs. 5 min.	6 hrs. 20 min.
28	5 hrs. 50 min.	7 hrs. 15 min.
30	5 hrs. 50 min.	7 hrs. 0 min.
35	5 hrs. 40 min.	7 hrs. 30 min.
40	5 hrs. 40 min.	7 hrs. 15 min.
50	6 hrs. 15 min.	7 hrs. 10 min.
60	7 hrs. 5 min.	7 hrs. 25 min.

Variations in humidity did not greatly affect the set, as witness:

Position of Test Piece	Initial	Final
In dessicator	4 hrs. 40 min.	6 hrs. 10 min.
In semi-humid air	4 hrs. 15 min.	5 hrs. 35 min.
In moist closet	5 hrs. 40 min.	7 hrs. 0 min.
Under water	4 hrs. 25 min.	5 hrs. 30 min.

Here the reason for the underwater test piece having a quicker set than the test piece allowed to set in the moist closet is probably due to its having a lower temperature due to the better conducting away of heat during the hydrating and coagulating stage; a lower temperature around 70° F. causing a more rapid set.

A few tests were made to see what effect fineness had on the set. These tests showed that an increse in surface caused an acceleration of set.

Fineness	Initial	Final
300 mesh sieve residue	11 hrs. 20 min.	15 hrs. 0 min.
As received	5 hrs. 40 min.	7 hrs. 0 min.
Through 300 mesh sieve	5 hrs. 0 min.	6 hrs. 5 min.
Ground very fine in agate mortar	0 hrs. 25 min.	5 hrs. 30 min.

Effect of Hydrating Previous to Gauging

	Initial	Final
Freshly ignited	4 hrs. 30 min.	6 hrs. 5 min
Partly aged	5 hrs. 40 min.	7 hrs. 0 min.
With 1.5% water	4 hrs. 5 min.	6 hrs. 15 min.
With 3.0% water	0 hrs. 35 min.	1 hr. 10 min.
With 5.0% water	0 hrs. 30 min.	1 hr. 10 min.

Although the quantities given above, 1, 3, and 5% of water, were added to the cement and shaken for some time, the cement did not absorb near this amount chemically but retained it mechanically.

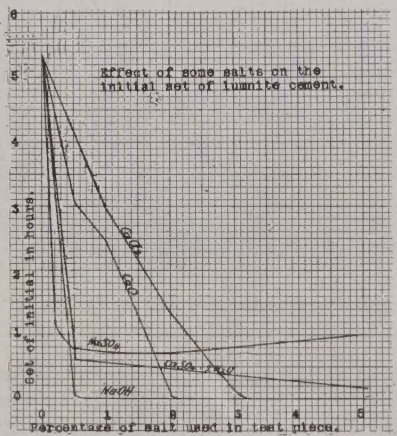


Fig. 4—Effect of some salts on the initial set of Lumnite cement

One per cent of common acids, bases, salts, and a few organic compounds were tested for their effect on Lumnite. When their percentage differs from 1% it is inserted in the table.

Acids	Initial	Final
Sulfuric	0 hrs. 20 min.	1 hr. 10 min.
Hydrochloric	3 hrs. 40 min.	A
Nitric	0 hrs. 20 min.	0 hrs. 35 min.
Hydrofluoric	0 hrs. 35 min.	5 hrs. 30 min.
Oxalic	2 hrs. 15 min.	12 hrs. 0 min.
Acetic	0 hrs. 35 min.	2 hrs. 25 min.
Chromic	1 hr. 20 min.	3 hrs. 0 min.
Carbonic	5 hrs. 30 min.	6 hrs. 35 min.
Chlorides		
.5% Sodium chloride	6 hrs. 35 min.	7 hrs. 15 min.
1 % Sodium chloride	10 hrs. 55 min.	15 hrs. 0 min.
2 % Sodium chloride	18 hrs. 0 min.	25 hrs. 30 min.
5 % Sodium chloride	19 hrs. 0 min.	30 hrs. 0 min.
.5% Calcium chloride	3 hrs. 20 min.	8 hrs. 0 min.
1 % Calcium chloride	2 hrs. 50 min.	9 hrs. 35 min.
2 % Calcium chloride	1 hrs. 20 min.	8 hrs. 55 min.
4 % Calcium caloride	Flash	Flash
Ammonium chloride	1 hr. 25 min.	27 hrs. 15 min.
Cuprous chloride	14 hrs. 45 min.	23 hrs. 0 min.
Barium chloride	15 hrs. 25 min.	21 hrs. 30 min.
Bases		
.1% Sodium hydrate	3 hrs. 55 min.	4 hrs. 10 min.
.2% Sodium hydrate	3 hrs. 0 min.	4 hrs. 20 min.
.4% Sodium hydrate	0 hrs. 5 min.	1 hr. 30 min.
1.0% Sodium hydrate	Flash	Flash
5.0% Sodium hydrate	Flash	Flash
.5% Lime (CaO)	3 hrs. 5 min.	4 hrs. 15 min.
1.0% Lime (CaO)	2 hrs. 25 min.	2 hrs. 55 min.
2.0% Lime (CaO)	Flash	Flash
3.0% Lime (CaO)	Flash	Flash
5.0% Lime (CaO)	Flash	Flash
Sodium carbonate	0 hrs. 40 min.	1 hr. 50 min.
Potassium carbonate	1 hr. 50 min.	8 hrs. 40 min.
Sodium bicarbonate	4 hrs. 10 min.	9 hrs. 35 min.
Barium hydroxide	4 hrs. 10 min.	7 hrs. 20 min.
Nitrates		
Ammonium nitrate	7 hrs. 0 min.	A
Barium nitrate	14 hrs. 45 min.	A
3 % Barium nitrate	7 hrs. 0 min.	12 hrs. 10 min.
5 % Barium nitrate	Flash	0 hrs. 35 min.
Sulfates		
.5% Sodium sulfate	0 hrs. 45 min.	7 hrs. 30 min.
1 % Sodium sulfate	0 hrs. 45 min.	3 hrs. 40 min.
2 % Sodium sulfate	0 hrs. 40 min.	3 hrs. 45 min.
5 % Sodium sulfate	0 hrs. 55 min.	3 hrs. 45 min.
10 % Sodium sulfate	0 hrs. 30 min.	2 hrs. 0 min.
.25% Gypsum	3 hrs. 35 min.	5 hrs. 35 min.
.5% Gypsum	0 hrs. 40 min.	6 hrs. 25 min.
1 % Gypsum	0 hrs. 35 min.	1 hr. 45 min.
2 % Gypsum	0 hrs. 30 min.	2 hrs. 10 min.
4 % Gypsum	0 hrs. 20 min.	1 hr. 35 min.
Ferrous sulfate	Flash	Flash
Potassium sulfate	1 hr. 10 min.	8 hrs. 50 min.
Various Inorganic Salts		
Ammonium Oxalate	5 hrs. 5 min.	14 hrs. 15 min.
Borax	27 hrs. 10 min.	A
Calcium carbonate	6 hrs. 5 min.	10 hrs. 0 min.
Manganese dioxide	6 hrs. 5 min.	9 hrs. 35 min.
Lead acetate	1 hr. 10 min.	4 hrs. 0 min.
Magnesium silico fluoride	4 hrs. 40 min.	11 hrs. 30 min.
Potassium ferrocyanide	2 hrs. 40 min.	A
Potassium ferrocyanide	B	A
Potassium bichromate	1 hr. 5 min.	17 hrs. 0 min.
Potassium chlorate	16 hrs. 35 min.	22 hrs. 0 min.
Potassium permanganate	3 hrs. 45 min.	15 hrs. 0 min.
Potassium iodide	B	A
Sodium nitrate	8 hrs. 50 min.	A
Sodium sulfide	0 hrs. 10 min.	1 hr. 25 min.
Sodium phosphate	7 hrs. 45 min.	14 hrs. 45 min.
Sodium silicate	6 hrs. 0 min.	25 hrs. 0 min.
Zinc oxide	9 hrs. 10 min.	10 hrs. 20 min.
Bromine	4 hrs. 30 min.	8 hrs. 5 min.
Iodine	2 hrs. 15 min.	12 hrs. 25 min.
Organic compounds		
Glycerine	2 hrs. 35 min.	C
Mannitol	1 hr. 10 min.	A
5% Alcohol	5 hrs. 50 min.	9 hrs. 40 min.
Sugar	8 hrs. 40 min.	C
5% Sugar	0 hrs. 30 min.	0 hrs. 45 min.
Petroleum	6 hrs. 0 min.	7 hrs. 25 min.

A = no final at 48 hours; B = no initial at 24 hours; C = no final at 72 hours.

A study of the above tables will show that the acids, bases, and sulfates accelerate the set of Lumnite, while chlorides and nitrates retard the set. Exceptions to this rule are ammonium chloride, where ammonia is evolved from the test piece while setting; therefore, giving an acid reaction, and the calcium chlorides and nitrates, the presence of calcium in any large amount (except as an insoluble salt) causes an acceleration of set.

The bases act as the most powerful modifiers of set, and their activity is proportional to their basicity. One per cent of sodium hydroxide will cause a flash, while 1% of sodium carbonate, a weaker base, will cause an initial set to occur in 40 min., and sodium bicarbonate, a still weaker base, will only accelerate the initial to 4 hrs. and 10 min., while the final is even retarded.

The influence of gypsum is the same as the other sulfates, causing an acceleration of set.

The action of portland cement on the set of Lumnite can be ascribed in considerable measure to both the gypsum and free lime contained in portland cement; the gypsum probably playing the major role, since ½ of 1 % of gypsum will shorten the set of Lumnite to 40 min. while a corresponding percentage of lime will only shorten the set to 3 hrs. and 5 min. for the initial. In confirmation of this, it was found that finely ground portland cement clinker without gypsum mixed 50% with Lumnite gave an initial set of 2 hrs. and 15 min.; whereas, portland cement containing gypsum mixed with Lumnite flashed at only 35%.

In the setting of a cement there are two physical processes whose rates probably determine the rate of setting of the cement. The rate of solution of the hydrating constituents, and the rate of settling, or coagulating, or crystallizing out of solution of the fully hydrated constituents.

The solubility of the aluminates in an aqueous solution of some set modifiers were tried as follows: Twenty grams of Lumnite with 5% of the set modifiers were agitated with 50 cu. cm. of cold distilled water for 10 min. and then filtered, and the filtrate analysed for alumina.

Set Modifier Used	% Alumina in Filtrate
Sodium hydrate	2.08
Gypsum	0.22
Distilled water only	0.68
Borax	0.00
Sodium chloride	0.72
Sodium sulfate	0.96
Lime	0.00

Although most of the above results indicate that the amount of solvent action of a set modifier is in conformity to its effect on the set, the solvent action of gypsum and lime is anomalous; however, when smaller amounts of lime were used, 1% and 2%, the amount of alumina dissolved was 0.93% and 0.96% respectively.

This anomalous action of lime and lime salts may be due to the taking up of lime by the weakly basic aluminates when hydrated tricalcium aluminate is formed instead of splitting off amorphous alumina. This however is a doubtful conjecture. Another conjecture is that the alumina is absorbed by the thick plastic fluid which results when 5% of lime is used in the above tests.

As with portland cement, nothing in general can be said about the action of oxidizers and reducing agents as set modifiers.

Although aliphatic hydroxy compounds are profound set modifiers with portland cement, they are more indifferent in their action with Lumnite cement. This may be due to the abscence of free lime in Lumnite, lime forming colloidal solutions with aliphatic hydroxy compounds.

The results obtained by varying the concentration of the reagent on the set are fairly consistent and indicate a uniform modification of set in the same direction with increase in concentration. However the tests made were not in sufficient quantity to justify this generalization, but the results show that the set of Lumnite is less erratic to variations of concentrations of the set modifier than portland cement, which is well known to change its set with some modifiers up to a certain concentration in one direction then reverses the direction of set change with further concentration. The universally used gypsum produces unusually erratic results in this respect.

Below is given a summary of the set properties of Lumnite, and a corresponding comparison of portland cement.

Condition or reagent	Lumnite	Portland cement
Temperature	An increase of temperature between 35° and 90° slows set	Increase of temperature hastens set.
Humidity	Does not greatly affect set	Affects set considerably.
Hydration previous to gauging	Increase of hydration greatly affects set	Increase of hydration slows set.
Percentage of water used in gauging	Increase of water slightly slows set.	Increase of water greatly slows set.
Fineness	Increase of fineness hastens set.	Increase of fineness hastens set.
Bases	Greatly hasten set	Generally hasten set.
Acids	Hasten set.	Effect variable.
Sulfates	Greatly hasten set	Generally hasten set.
Chlorides	Retard set	Generally hasten set.
Nitrates	Retard set.	
Moist carbon dioxide.	No effect	Greatly hastens set.

Central Mixing Plants for Concrete

In discussing the possibility of retail dealers mixing and selling wet concrete, it is pointed out by Charles R. Miller, vice president, Southern Material and Construction Co., in an address delivered at the Fifth Annual Convention of the Associated General Contractors, that central mixing plants have been established in a number of communities and have proved successful commercially. Wherever these plants are in operation, sales of cement and aggregates have been increased by the ability of the builder to buy his concrete ready mixed and without the annoyance and inconvenience of mixing his own material.

The fact is cited that Prof. Duff A. Abrams of the Structurals Materials Research Laboratory, Lewis Institute, Chicago, has made tests which, although far from being complete, indicate that no appreciable loss of concrete results in cases where the concrete has stood for a period of from three to four hours. Professor Abrams is quoted as stating that "there is apparently no objection to a central mixing plant from the standpoint of the effect upon the concrete. It will be found a matter of practical handling that considerable attention will have to be given to the consistency of the concrete in order to prevent separation of water on the one hand and the concrete from becoming too much compacted on the other."

Based upon Mr. Miller's experience, the real problem for a commercial plant is the consistency of the concrete. If a plant were designed to operate on the same consistency, day by day, the problem would be simplified. The finished mix must be a stiff, quaky consistency as a sloppy mix would have a tendency to separate water from materials and would also give trouble in ejecting the concrete from the truck into the receiving forms.

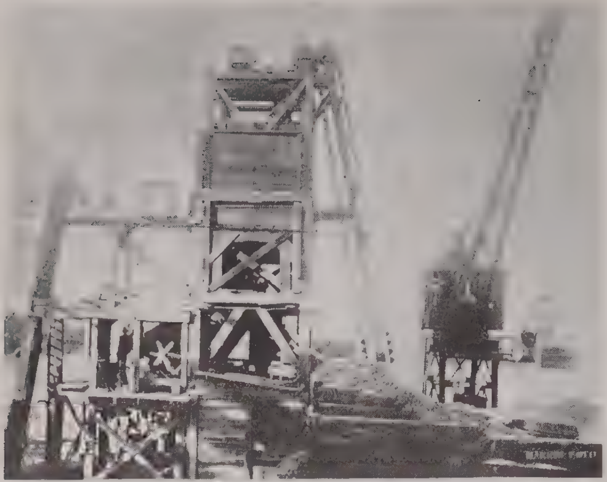
At the first known central mixing plant to be erected in this country for commercial purposes, located at Kankakee, Ill., and owned and operated by the Shidler Construction Material Co., the customer may be given any mix he desires. The method of proportioning the cement, stone, sand and water is such that it is just as convenient to change the mix with each turn of the mixture as to run continuously on a given specification.

Another decided advantage to the builder in the use of premixed concrete is pointed out. There is no congestion of materials scattered around the job, either during or immediately following the work. When the concrete is placed, that part of the job is finished. There are many jobs in every community that contractors would develop if it were not for the fact that they are too small in size to warrant the removal of the mixer to the job. Work of this nature can conveniently be accepted by the contractor where there is a central mixing plant in operation. The use of premixed concrete also solves the problem that may arise at other times when a contractor's mixer is busy on one job and he desires to start a second crew on another job.

There are three points of importance that should receive the constant attention of the individual in charge of the operation of a central mixing plant:

1. Careful attention to proper gradation of aggregates. Whenever necessary changes should be made.
2. Sufficient amounts of water must always be used but never a surplus of water.
3. Proper mixing of the cement, water and aggregates and enough of it.

An adjustable measuring batcher such as the Blaw-Knox equipment is recommended as it does away with the necessity of having to depend upon a workman to see that the measuring boxes are always properly filled. With the proper adjustment of the measuring batchers, both the dealer and the purchaser will know exactly the volume of each class of



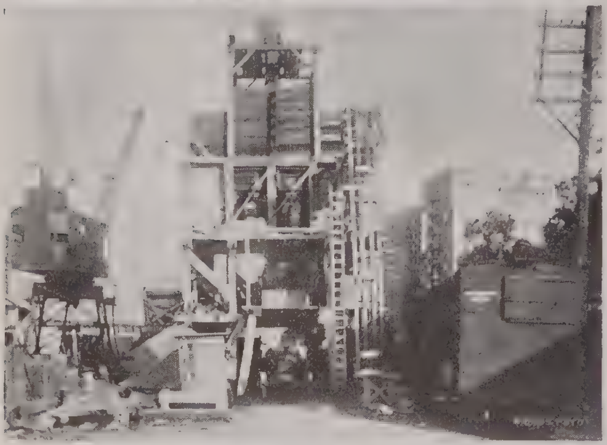


Fig. 1—Central concrete mixing plant. The bag elevator is on the left, the sand and rock elevator on the right. The bottom of the elevator is located between the piles of sand and rock, a slide-door permitting the introduction of either class of material Fig. 2—On this central mixing plant the Blaw batcher boxes are located on the platform above the mixer. The mixer is somewhat higher than it need be because originally there was an intermediate box for holding wet concrete when trucks were not on hand. It has been found best to take the intermediate box out

material that is desired will be going into the mix. After the measuring devices are once set where desired, absolute uniformity of batches will be assured. The entire job of charging the mixer and delivering the mixed concrete to the truck for hauling to the job can easily be handled by one man where bulk cement is used.

One of the difficulties reported as being encountered by the beginner in hauling ready-mixed concrete from the central mixing plant, is to get it out of the dump truck body, particularly in cases where the least bit of excess water is present. It has been found that a clean well polished iron body will usually clear without trouble. It has been recommended in cases, that the truck body be oiled before the load is taken on, but this is apt to give trouble as the oil may mix somewhat with the concrete causing oil stains on the surface. Among the devices used to clean out concrete from the truck bodies and boxes are included false bottom for trucks and compressed air jets for cleaning concrete boxes. The sliding or false bottom has proved a very good device for assuring complete dumping of the concrete. The front end of the false bottom is bent up so that the top projects above the height of the concrete when the body is loaded. It is slightly narrower than the bottom of the truck body so as to allow the sliding motion without binding against the sides; a short piece of strong chain about 12 in. long connects the front of the false bottom with the front of the body and when the truck is dumped, the load and false bottom together move down until the slack is taken out of the chain with a sudden jar which causes the concrete to clear itself and move out of the body.

Cost Figures

Some reasonably accurate figures on labor costs covering 8 mo. operation of a plant with an output of slightly over 15,000 cu. yds. of concrete in that time have been kept by Mr. Miller. The plant consists of a mixer having a capacity of 1 cu. yd. This mixer is set upon an elevated platform under which trucks can be backed to receive the wet concrete. Storage bins are located a sufficient distance above the mixer to have Blaw batcher boxes between the bins and the mixer.

The concrete plant is operated in conjunction with the sand distributing plant, one clam shell crane handling materials for both operations. The laborers are transferred at times from one plant to the other and vice versa so that it is not an easy matter to secure absolutely accurate labor costs.

The locomotive crane handles the sand from barges to the elevator which takes it up into the storage bin above the mixer. This crane also handles crushed rock and gravel from railway cars to the same elevator. A cement storage house is built underneath the material bins. There is a bag elevator to raise the cement up to a loading platform. Much of the cement is handled directly from this car to the elevator. The labor cost under the above arrangement is reduced to a low figure.

With common labor varying from 25c to 30c per hr. and skilled labor between 50c and 60c per hr. the average labor cost covering the handling of the material, feeding the mixer and operating it, or everything covering the movement of raw materials after their delivery in cars or barges at the yard to delivering the mixed concrete into sacks or other transportation, is 37.5c per cu. yd. for the 8-month period and output of 15,280 cu. yds. Possibly 75% of this material was hauled within a radius of 2 miles, a small portion as much as 8 miles. The average hauling cost was 65c per cu. yd. figuring trucks at $2.00 per hr. Interest, depreciation, power fuel and overhead will vary under different conditions and hence are not given to cover this operation.

The selling prices vary with the cost of the raw materials in different localities. At the plant described, 1:3:6 concrete is delivered f. o. b. the plant at $7.00 per cu. yd.; 1:2½:5 at $7.50; 1:2:4 at $8.00 and 1:2:3 at $8.25 per cu. yd. A plant in California delivers at $7.00, $8.00 and $8.50 for the first three classes respectively but it does not give any price on a 1:2:3 mix. A Texas plant delivers f. o. b. trucks at $6.10, $6.60, $7.10 and $7.60 respectively. This plant uses pit-run gravel which is obtained at $1.55 per cu. yd. f. o. b. the plant.

The following excerpt from a letter from the Texas plant above referred to gives some interesting information from the viewpoint of the companies producing premixed concrete:

> We have sold concrete for nearly every possible purpose. The most desirable customers are the large users, naturally. With us, the largest users have been smaller paving companies putting on paving in suburban additions, and to sewer contractors. We have also sold a great deal of concrete to general cement contractors who build sidewalks, foundations, floors, etc. The building contractors have bought concrete for foundations, floors, etc. Some of this concrete has been used in places where it was handled in elevators and in many cases where wetter concrete was desired, additional water was used on the job.

The following prices are quoted by the Los Angeles company which handles nothing but ready mixed concrete:

Deduct 50c per cu. yd. if account is paid within 10 days. Cartage $1.00 per cu. yd. for first zone (1½ miles), 12½c per cu. yd. for each additional zone (½ mile).

50-50 Mix (3 Sacks Cement)	$ 5.85 Cu. Yd.
50-50 Mix (4-Sacks Cement)	6.50 Cu. Yd.
1:3:6	7.00 Cu. Yd.
1:3½:5	7.15 Cu. Yd.
1:3:5	7.50 Cu. Yd.
1:2½:5 City Spec. Sidewalk	8.00 Cu. Yd.
1:3:4	8.00 Cu. Yd.
1:2:4	8.50 Cu. Yd.
1:2½:3½	8.25 Cu. Yd.
1:2:3½ City Pav. & Gutters	8.75 Cu. Yd.
1:1½ Top Mix	13.25 Cu. Yd.
1:2 Top Mix	11.00 Cu. Yd.
1:3 Top Mix	9.25 Cu. Yd.

All prices f. o. b. our plant. Cartage extra.

Crazing on Cement Products

By P. H. Bates

Published by permission of the Director of the Bureau of Standards of the U. S. Department of Commerce.

A paper presented at the 21st annual convention of the American Concrete Institute, Chicago, Ill., February 24-27, 1925.

Published by courtesy in advance of copyrighted *Proceedings*, vol. 21, 1925.

The title is purposely chosen because the three common products using cement as a bond all show crazing. This difficulty is not restricted either to neat cement or mortar or concrete. So far as cement products are concerned we are all familiar with the manifestation of crazing. Some believe they know the cause of this and a still smaller number believe they know how to prevent it. (Parenthetically, they are eligible for membership on this committee provided they will demonstrate facts and not present theories.) Consequently this paper will not discuss crazing objectively but metaphorically only subjectively. Furthermore, it should be borne in mind that while I am occupying the time allotted to Committee T-1 this discussion is the product of my own thoughts, and the members of the committee should in no wise be adversely criticised for any of the statements contained herein. Any other criticisms will of course be highly acceptable and appreciated by them.

Crazing is not new. It undoubtedly developed in the first product made by the original consumer of Joseph Aspdin's personally made portland cement, assuming that he not only first patented it but also first made portland cement. But crazing is much older than this. Our hypothetical first parents, if they were as observant of other natural phenomena as they were of the fruition of apples, undoubtedly noted it in the first dried up mud puddle they came across. As we are all convinced that the mud puddle preceded man on this sphere, so we must acknowledge that crazing is older than humanity. When man decided to improve upon the habitation furnished him by nature and build himself mud houses he found this occurrence of nature following from the puddle to the mud houses. When he started making utensils or writing materials of dried or partially burned mud he again found crazing an inherent difficulty. But when he tried protecting surfaces of burned clay products with glazes, or surfaces of wood or steel, etc., with paints or enamels he found crazing so persistent that he practically assumed it was inevitable and accepted it without any question or further thought. This attitude maintained for centuries and even today certain makes of pottery are in demand because they do craze.

It might be well to consider the ceramic industry and its problem of crazing as typical of an industry which was unquestionably the first to encounter it and which has studied it and is still studying it so intensely that it is in a fair way towards solving its difficulties. Glazes were placed upon soft open porous ware not only to enhance it but to reduce its absorption and abrasion. The glazes in contrast to the ware were hard and not absorptive. In other words they were distinctly different and it was early recognized that this difference was the cause of the difficulty. As a consequence the plant expression for the cause of crazing of ceramic ware originated, and is indeed expressive—"fit" or "lack of fit"—the former indicates lack of crazing and the latter, crazing. The industry recognized that if the coefficient of expansion of the unglazed ware and the glaze, and the modulus of elasticity of the two are too widely different then the glaze does not fit the ware and crazing must result. The same condition exists in the industries engaged in making cement products. If the surface does not fit the interior or body of the product crazing will result. The cause will again be the same, namely, differences in the coefficients of expansion with temperature changes, differences in the moduli of elasticity, and a third condition which does not exist in the pottery industry, a different coefficient of expansion due to absorption of water. We are purposely leaving out of this paper any discussion of strength. It is important and necessary in the question of crazing, but the strength consideration of cement products has been discussed so much to the total exclusion of all other considerations that to concentrate attention on the latter we will exclude strength in this discussion completely.

The simple statement of these considerations, however, does not assist much in solving the problem. Take for example the modulus of elasticity. We have become so accustomed to using the value of 3,000,000 for this coefficient that it is now almost axiomatic. But read what Walker has found and published in Bulletin No. 5 of the Structural Materials Research Laboratory, and note that the value is a function of the size of the aggregate as well as its grading, the consistency of the mix, the amount of the cement, and the age of the concrete, to which must be added the character of the cement and the character of the atmosphere in which aged, as to humidity, temperature, etc. The two other coefficients mentioned are affected in the same way. Hence, must not a study of the cause and prevention of crazing embrace a study of these three coefficients, and how the cement, the aggregate, the mixing water, the air, and the personal equation affect these?

CEMENT

Assuming that these premises are correct, let us consider in more detail what we are "up against." First let us discuss the cement. I have already told the members of the committee that with myself as chairman it will always have in mind and carry out all tests with *cements* and not *a cement*. If it wishes to restrict itself to a cement or to an assumed average cement obtained by mixing representative brands it must operate under another chairman. Here we must assume that practically all portland cements are different, and mixing gives only an average of that mixture. The average prepared tomorrow by mixing samples of the same brands will quite likely give different results. But what data do we have of the character outlined above as requisite? The answer is none. We must have values for these three coefficients of a variety of different cements, aged under different conditions, and with ranges of consistencies deviated very much from the so-called normal consistency. It must be borne in mind that on the trowelled surface of a floor or the skin coat on concrete we have very largely neat cement, and here crazing is invariably manifest. But this is enough for cement, for more could be written about what we do not know of this commodity than of what we know.

AGGREGATE

Next we have the aggregate to consider. Here there is more information available but far more needed. For instance what do we know about the coefficient of expansion of any concrete in a saturated atmosphere, in a 50% saturated atmosphere, and in a very dry one? There are several well-accepted coefficients, but on examining the original articles in which these values appear we do not find any data which will enable us to reproduce these concretes, other than the simple ratios of cement to sand to large aggregate. These data were obtained by those who did not appreciate the importance of size or grading or volume of aggregates, or the differences between the various kinds of crushed stone, gravel, slag, etc. Apparently any 1:2:4 concrete was representative of all 1:2:4 concretes, so long as the cement was purchased as portland cement, the fine aggregate as sand, and the large aggregate anything graded between ½ in. and 3 in. regardless of whether it was uniformly graded or all one size—and no notice made of these facts. It has been shown, and it is now an accepted fact, that the quartz gravel is a poor aggregate to use as a fire resistant agent, due to the sudden increase in volume of quartz at a fairly moderate heat, as it changes from one form to another. Possibly other forms of aggregate have just as undesirable coefficients at atmospheric temperatures, even though there is no conversion from one form to another, but our information is lacking.

WATER

Water, the third item needing study, is one that has been so properly and effectively emphasized for the past 10 or 15 years that its true relation to concreting values, as regards strength and certain kinds of durability, is now recognized. We also have data showing how different amounts of mixing water affect the elasticity. We also in general believe that excess mixing water results in excess shrinkage or drying. But with these, our knowledge and our beliefs on the effect of too much or too little water largely cease. It is our pleasure generally to look to the other side of the street in deference to our enthusiasm in concrete as we pass, as pass we must on our way from the bureau to the business center of Washington, a very long series of exterior steps leading up to an imposing mansion. The owner of the latter is a builder and contractor and is the author of his own steps. If he would have purposely tried to demonstrate how excessively exterior stairs may craze he could not have succeeded more eminently. He has never inflicted a more unsightly job upon a customer than he has upon himself. We have often wondered if they were not made in the typical manner, that is, a very dry base rammed against wooden risers, and then finished with a rich mortar. Most of the hydration of the base has taken place by means of rain water penetrating the rich mortar, with the result of the marked expansion of the base and crazing. Incidentally, one of our committee members believes that crazing is due to expansion and not contraction, and we believe that he is right, as are also those who believe it is caused by contraction. But evidently both are not right at the same time. In any case do we know that water will not cause contraction as well as expansion, depending upon whether the optimum amount has not been reached or exceeded? We may feel unduly optimistic, but we feel sure that if the committee ever does real work and produces a worth-while report it will have made a valuable contribution to the question of volume changes in concrete, although it is specifically dealing only with linear changes on its exterior. Water—both that used in mixing and that absorbed or given off in life, is the big factor after the cement, in volume changes and in crazing.

ATMOSPHERE

The atmosphere is the next item that must be taken into account in any discussion of crazing. This has been recognized for a long period and is evidenced partly by the covering of concrete roads with various materials to prevent the rapid evaporation of the mixing water. But noting this the critical observer must ask why we do not logically treat concrete sidewalks in the same way. Some may say that the road does not craze but the sidewalk does. The answer to this argument is that the road does not show the crazing as prominently as the sidewalk, but it is not yet definitely proved that the saturated atmosphere is the ideal one for hardening of all concrete. If all the water used in making concrete and needed in mixing it were combined and so fixed in it as a result of the hardening phenomena that it would never be lost, I am thoroughly convinced that the concrete would be valueless, for it would be a soft product, in no way giving the service required of it. It would mean in general that the cement in concrete would have combined with it a weight of water from 50 to 100% of its own weight. We do know that hydrated cement containing that amount of combined water has no bonding value. Consequently, since a very considerable part of the mixing water must be removed, when shall it be removed? Shall the concrete be kept saturated for a month and then allowed to dry as rapidly or as slowly as the atmospheric conditions permit? The answer is, candidly, not known. The proper atmosphere for the proper hardening of concrete is yet to be determined.

There is reserved for the final citation that large group of variables which are constant only in that they are constantly before us. One of the outstanding items in this group is the so-called personal equation, evidenced by that peculiar propensity of human nature to do a thing in one way and more or less believe and report that it has been done in another. As an extreme instance we have the giving of data showing 10 or 12% water used, whereas 17 to 20% went into the job, or making a 1: 1½: 3 concrete according to specifications and a 1 :2 : 4 according to bills rendered by the sand and gravel dealers. Then we have the more common cases of the lack of proper knowledge of materials introducing variables, such as a lack of taking into account the variable moisture in the aggregates, the lack of uniformity of grading, the lack of uniformity of mixing, etc. We also have a variation in the character of the sub-grade, the form, the molds or the backing, all of which introduce factors concerning which we know so little. Such a group of extremely difficult items to control does not tend to uniformity in production, but at the same time it furnishes conditions which must be studied in part at least in order to have available more readily enforced precautions as would tend to reduce the difficulties which are the subject of the work of this committee.

It might be inferred from portions of this discussion that the way to avoid crazing would be the doing away with any surfacing on concrete, and consequently no investigation would be needed. This is true in part, and could we always have the surface on the cement product identical with the rest of the piece we undoubtedly would not have crazing. Nevertheless, volume changes might produce a cracking which, however, would be distinct from crazing. But there are so many cases where a surface is intentionally or unintentionally produced that due consideration must be given to its cause and prevention.

This paper is presented especially to bring to the Institute the thought that crazing is no simple problem, to be solved by a field examination followed by a more or less perfunctory laboratory research, and climaxed by a voluminous, well-illustrated report, unanimously signed by the committee members. On the other hand it is a problem which will cost the active services of several trained investigators over a period of years, and in which a committee can act only in an advisory capacity, as a collator of data, and in giving a breadth of view to the discussion and the problems of the latter. The committee itself cannot solve the problems involved. No committee can. The problems are not of that type. The committee needs that kind of co-operation which is so difficult to obtain—financial—either direct contributions of funds or the services of investigators placed at its disposal. It will have a first meeting during this convention and formulate methods, procedure, and possibly a program. How successful it will be in obtaining this co-operation will be the subject of the first report of this committee.

Recent Conclusions in Highway Research

By A. T. Goldbeck
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From *Public Roads* (Published by U. S. Bureau Public Roads) January, 1925, p. 9.

To one in a position to survey the whole of the wide field of highway research and appreciate the relations of the various efforts made by numerous agencies one to another, there has come within the last year a very pronounced sense of a gradual convergence of the facts brought out by these efforts toward a well defined and rational process of highway design. Viewing the various single experiments separately, one is apt to lose the sense of their position in the entire scheme and to miss the full appreciation of their value. It is therefore a good thing to stop for a moment occasionally and review the whole field, and obtain a new orientation to guide our further progress.

In attempting such a review at this time it may be well to consider not only the definite conclusions that have been reached, but also to include certain well defined indications which may later resolve themselves into conclusions. Through a knowledge of these indications it may be that much valuable time will be saved in the process of making the results of research a part of everyday practice.

THE SUBGRADE

All highway engineers have observed the fact that the soils encountered in highway construction are variable in their behavior. They have observed that some of these soils shrink and crack when they become dry and swell upon taking up moisture; that some of them absorb large quantities of moisture by capillarity from below and are utterly incapable of carrying load when in a moist condition, while others, retaining uniformly low moisture content, are very stable, change only slightly in volume, and are affected little in their load-carrying ability. The characteristics of the various soils shade from one of these extremes to the other, and the question naturally arises as to what is the dividing line between good and bad soil characteristics from the highway engineer's standpoint and how should he take account of these variable characteristics of soils in highway design.

One of the first steps toward an answer to this question was to develop suitable tests in the laboratory for classifying soils according to characteristics which would be significant to the highway engineer; and we may now say definitely that we have succeeded in developing suitable tests for differentiating the various shades of quality in soils. The details of the tests developed have been described elsewhere. They include determinations of shrinkage, moisture equivalent, water absorbed by capillarity, slaking value, dye absorption and bearing value, as well as the more familiar mechanical analysis[1]. A combination of some of these will serve to identify the essential characteristics of a subgrade material.

We have reached the stage where, for all practical purposes, we can conduct these tests in such a way that we can get identical results with identical samples. This is an important conclusion to the testing engineer but the highway engineer wants to know what test values are the significant ones, what values indicate bad soils and what values good soils. Research has advanced a long step in this direction but a true evaluation of the test results of subgrade samples must ultimately be arrived at through the coordination of a large number of laboratory tests with field behavior. Such coordination is a difficult task, for in addition to the influence of the subgrade in causing success or failure of a road surface, the coordinator must recognize and eliminate the influence of a large number of factors such as weight of traffic, condition of drainage, strength of materials, method of construction, and suitability of the design of the road surface for the traffic carried. By and large, however, it has been possible to make a step in the direction of coordinating laboratory test results with field behavior. Much credit is due to A. C. Rose, of the Bureau of Public Roads, District No. 1, Portland, Ore., for his successful efforts toward this end. As a result of his work, the indications are very strong that when a soil has a so-called "moisture equivalent" in excess of 20% or a lineal shrinkage value in excess of 5%, it is apt to be unstable in that it will take up excessive amounts of moisture and consequently heave readily due to frost action or change excessively in volume due to moisture changes.

Under such conditions special precautions are necessary to insure against failure of the pavement due to subgrade movement. Thus, drainage, both surface and tile, might have to be provided to remove water in excess of capillary moisture. The pavement might, however, be strengthened by increasing the depth, by the use of steel or by the use of a layer of stable subgrade material. Sand or a similar cushion might be provided under the road surface or the soil might be treated to render it more stable by the use of admixtures.

Suitable field tests have been developed for determinating the so-called "moisture equivalent" of the soil and this test combined with the shrinkage test, which might also be made in the field without elaborate equipment, gives an excellent idea as to whether or not subgrade trouble is to be expected. The ability to perform these two tests and to interpret them should be a part of every field engineer's equipment, and they should be used and the results noted, for they are highly significant.

THE IMPROVEMENT OF BAD SUBGRADES

When a bad soil is encountered in road construction the question naturally arises as to what is the best thing to do with that soil or with the design of the road under construction. Years ago railroads both in this country and abroad discovered that in order to prevent the subsoil from working up through stone ballast it was necessary to provide a layer of fine granular material. In general, cinders have been used for this purpose but so also have bank-run gravel, ashes, and in one case it has been reported that cement was mixed with the soil. A bad soil primarily is one which has the ability to take up a large amount of water by capillarity, and which swells and shrinks excessively with changing moisture content, and which also has low bearing value in its moist condition. Such properties make it a poor supporting medium for highways and when the subgrade is to be improved it should be treated in such a way that: (1) It will have low shrinkage and expansion; (2) it will have high bearing value at its highest moisture condition; (3) it will retain as little moisture as possible.

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[1] See *Public Roads*, vol. 4, No. 3. p. 15.

The sand-clay road furnishes an excellent example of the treatment of bad subgrades. Sticky, plastic clay is made into a stable non-yielding surface by the addition and admixture of sand. Cinders, or other fine granular material will accomplish the same end. These processes are so well developed that the following can be set down as an absolute conclusion:

> A poor subgrade material can be transformed into a good subgrade by the addition of sufficient fine granular material or by the use of a layer of suitable granular material.

Effect of Size of Bearing Area on Bearing Value

If the bearing value of the subgrade is important, the question immediately arises as to what effect the size of the bearing area has on the supporting value of the soil. The importance of the series of investigations described for the first time in this number of *Public Roads* is that it apparently provides the answer to this question.[2] As the tests themselves are described on another page[2] it will not be necessary to describe them in detail here, or to go into these conclusions except to repeat their most important conclusion, as follows:

> When like intensities of load are applied to bearing blocks of different size, the relative penetrations of these areas into the soil will vary as the square roots of the areas.

This means that a large area will penetrate more than a small area when both are loaded with the same load per square foot. This will be an important conclusion to those interested in the design of footings for structures. It applies so long as the loads and the penetrations are relatively small thus enabling the soil to act largely elastically. Its application to large areas resting on a subgrade of unlimited depth has yet to be demonstrated.

Blanket Courses

In many States it is still the practice to build macadam on all kinds of subgrades in exactly the same manner as when this type of construction was introduced by John Louden McAdam. A layer of rather uniform coarse stone is laid directly on the subgrade in this type of construction. Under the action of the present-day heavy loads, and under the action of the roller, the subgrade materials, especially plastic clay materials, find their way up through the voids in the stone. The stone is thus lubricated with moist clay and the surfacing is thereby rendered much less capable of supporting loads because its effective depth is greatly decreased.

> It has been proved not particularly by theoretical tests but rather by actual construction in a number of different localities that a blanket course of fine granular material such as cinders, bank sand or gravel is very effective in preventing the clay subgrade from penetrating upward into macadam and its resistance to loads in this way is very greatly increased.

There is nothing new about this method. It has been practiced for years but its advantages seem not to have been universally recognized and it is well to emphasize them again at this time.

Drainage

High moisture content in the subgrade is detrimental to road surfaces: (1) Because the bearing value of the subgrade is greatly decreased; (2) because the effect of freezing in causing unequal heaving of the road surface is more severe; and because (3), when the moisture dries from the subgrade, this drying is accompanied by considerable shrinkage of certain types of subgrades with a resulting non-uniform support for the road surface. The amount of harm which moisture can do is, of course, closely linked with the characteristics of the subgrade material. Moisture may be said to exist in the subgrade in the form of vaporized moisture, capillary moisture and free moisture. Free water is water which will drain out of the soil if a drainage system is provided, whereas the amount of capillary moisture is unaffected by any drainage system. When soils have an ability to take up large amounts of capillary water all types of drainage seem to be ineffective in preventing these soils from becoming very wet under the road surface and generally the water is supplied by capillarity at a higher rate than it can evaporate from beneath the surface. The investigations thus far made point very strongly to the following facts:

> Water exists in the subgrade: (*a*) As free water, (*b*) as capillary moisture; (*c*) as vaporized moisture.
>
> The moisture content of the subgrade is apt to increase under low temperature conditions due: (*a*) To the condensation of vaporized moisture, (*b*) to increase in capillary moisture.
>
> Drainage systems should be provided wherever free water is likely to exist but such systems are quite generally ineffective in removing any moisture in excess of free moisture.

Experiments in Connection with Road Design

A number of investigations have been made during the past year in connection with road design. They include both impact and static load tests on road slabs of different design laid at Arlington, Va., stress measurements in concrete roads, and special observations on a reinforced concrete road known as the Columbia Pike, near Arlington, Va.

The tests conducted at Arlington were made on 124 slabs of different design, some of them laid on a wet subgrade and some on a dry subgrade. They were tested in positions which are known to give the most severe stresses, namely, at the corner and along one of the edges. The tests were made first with an impact machine delivering blows, the range of which covered the range of blows known to be delivered by actual motor trucks. The conclusions thus far reached with regard to the different slabs are as follows:[3]

> The resistance of a road slab depends in part upon the supporting value of the subgrade. A subgrade of high supporting value materially increases the resistance to impact pressure.
>
> Impact resistance of rigid slabs varies neither directly as the depth of the slab nor as the square of the depth but as some power less than two.
>
> In general, plain concrete slabs show no more resistance to impact delivered at the edge than to impact delivered at a corner.
>
> Transverse cracks and longitudinal cracks near the sides of a road slab may be caused by impact delivered at the edge of the slab.
>
> Plain concrete of 1:3:6 mix offers resistance to impact ranging from about 60% to 80% of the resistance of plain concrete of 1: 1½ : 3 mix. The lean mix also shows more variation in strength.
>
> Reinforcing steel in concrete slabs, if present in sufficient amount and so placed as to receive tensile stress, adds to the resistance of the slab to impact.
>
> Reinforcing steel placed longitudinally and transversely in equal percentages is more effective in preventing corner failures than the same amount placed in one direction.
>
> For a given percentage of steel, small deformed rods closely spaced seem to be more effective than large deformed rods widely spaced.
>
> There is very little evidence of cushioning by bituminous tops on concrete bases at temperatures of 90° F. or less.
>
> In these tests there was no evidence that bituminous tops on concrete bases added to the slab strength of the base, with the possible exception of the 4-in. and 6-in. bases on the dry subgrade.
>
> In some of the tests there was evidence that while the presence of the steel did not assist greatly in preventing the formation of the first crack it did prevent the development of the crack and the further failure of the slab.

The portions of slabs left unharmed have subsequently been tested under static load, both at the corners and along the edges with the following results:[4]

> The static resistance of both the corners and the edges of rigid slabs is affected by the nature of the subgrade; the more resistant the subgrade to load, the greater the resistance of the slab and vice versa.
>
> The resistance of rigid slabs to static loads does not vary with the

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[2] *Public Roads*, January, 1925; vol. 5, No. 11, p. 1.

[3] Impact tests on concrete pavement slabs, by L. W. Teller *Public Roads* April, 1924, vol. 5, No. 2, p. 1.

[4] Static load tests on pavement slabs, by J. T. Thompson, *Public Roads*, November, 1924, vol. 5, No. 9, p. 1.

square of the depth but as some power greater than one and less than two. About 1.75 is the average value, the exponent being higher for slabs on the wet subgrade and lower for those on the dry subgrade.

The corners and edges of concrete slabs of the size and thickness tested offer about the same degree of resistance to static loads.

The presence of mesh reinforcement as employed in the slabs under consideration, does not increase the load-carrying capacity of concrete slabs but does give rise to a tendency to hold together and resist complete failure after initial or elastic failure has taken place.

Bituminous topping laid on rigid slabs does not increase the resistance of the slabs to static load.

At the ordinary summer temperatures encountered, bituminous slabs of the types tested show no slab strength. The load supporting value of such slabs is greatly influenced by the subgrade support.

STRESS MEASUREMENTS IN CONCRETE PAVEMENTS

By the use of a graphic strain gauge developed by the Bureau of Public Roads a large number of measurements of fiber deformations have been made in concrete pavements of different design in order to determine the effect of traffic loads on the bending stresses produced in the slabs. The instrument has proved to be useful for determining both static and impact stresses and furnishes a means for determining whether or not concrete roads are overstressed.

The procedure in making these measurements has been to install a number of graphic strain gauges just beneath the surface of concrete pavements, placing the instrument in positions which will permit of determining longitudinal and transverse stress in important positions throughout the slab. Heavy trucks are then run over the pavement in different positions, first with the rear wheels along the outer edge, then several feet from the edge, and finally with the wheels trailing along the center joint, if any exists. The following conclusions are drawn from these tests:

In slabs of uniform thickness the highest longitudinal stresses exist along the edge and along the center joint. They occur with wheels running directly over the edge of the slab and along the center joint. The highest tension might occur either at the bottom or the top of the slab at the edge High tension also occurs transversely at a transverse joint The tension developed at intermediate positions is very much smaller. It is therefore most important that the edges of a slab be made of sufficient thickness so that the bending resistance along the edge will not be exceeded. This applies to all edges, whether they be along the side, at the center joint, or at a transverse joint.

If there is a center joint with no means for transferring load across the joint, the edge along the center joint is stressed to about the same amount as the outside edge of the pavement and should be of the same thickness. When an effective means is provided, however, for transferring load (such as tongue-and-groove construction), the stress along the center joint is considerably decreased.

High tension is produced in the top of the slab near a corner. This tension occurs with a heavy wheel load at the corner. It is, however, considerably less than the longitudinal tension along the bottom outside edge of the slab directly under a heavy wheel load.

A concrete slab should have a thickened edge in order to receive uniformly distributed maximum stress under traffic. This conclusion bears out the conclusions which have been reached as a result of the Pittsburgh test road and of the Bates test road.

When a center longitudinal joint is provided with an efficient means for transferring load across the joint, the thickness of the slab at the joint should be equal to not less than 0.7 of the thickness at the outside edge in order that like maximum stresses will be received in these two positions.

It is quite strongly indicated that any road roughness or truck conditions tending to produce impact will likewise greatly increase the fiber deformation and the possible likelihoood of cracking on this account.

It is quite evident that maximum stresses under the edge of the slab are produced only with the truck wheel trailing along that edge, and that these stresses are very greatly reduced when the truck wheels trail along a line no more than 1 foot distant from the edge. This suggests that where curbs are used which prevent the traffic from reaching the extreme edges, thickened edges probably are not necessary.

INDICATIONS FROM COLUMBIA PIKE EXPERIMENTS

The Columbia Pike investigations have been described in the October, 1924, issue of *Public Roads*[5]. Briefly the road consisted of 32 sections of both plain and reinforced concrete. The variations in the sections consisted of changes in thickness, changes in cross-section design, the use of cinders under some of the sections and the use of various percentages of reinforcing steel.

Careful observations were made of the development of cracking in the sections and subgrade samples were taken from time to time to note the moisture content and also physical characteristics of materials under various sections of the road.

An analysis of the subgrade samples and of the physical condition of the pavement as revealed by the record of longitudinal cracking indicates that the subgrade has a decided influence on the condition of the pavement. Materials subject to high volumetric change and having high "moisture equivalents" generally produce the most extensive longitudinal cracking. The most striking observations from these tests, however, have to do with the behavior of the various sections as influenced by the amount of longitudinal reinforcing steel.

In sections which have from eight to fourteen ¾-in. round deformed rods placed longitudinally, transverse cracks have occurred at frequent intervals a few feet apart. These cracks, however, are very fine. Sections which have eight ¾-in. rods have not cracked as frequently as those having fourteen ¾-in. rods. One section having four 1-in. rods has cracked slightly less than sections having eight ¾-in. rods. Sections which have reinforcing varying from four ¾-in. to four ½-in. rods are free from fine transverse cracks but have wide, open cracks similar to those found in plain concrete sections but spaced at greater distances—60 to 70 ft.—as compared with 40 to 50 ft. in plain concrete slabs. Sections which are reinforced with 25 and 50 lbs. of mesh per 100 sq. ft. have no fine cracks, but do have open cracks spaced at greater distances than would ordinarily be found in plain concrete. In order to discover the cause for the action of these several sections, the cracks were opened in a number of instances, thus exposing the steel.

It was found that in those sections having eight or more ¾-in. deformed round bars, no change in diameter of the bars had occurred. In the section reinforced with four 1-in. bars, slightly reductions in diameter were found. In the section having four ¾-in. bars, the diameter was reduced to ⅝ in. In the sections having eight ½-in. rods the diameter has been reduced to approximately ⅜ in., while in still another section having only four ½-in. bars the bars had completely broken with a reduction in diameter to about ¼-in. In sections reinforced with mesh to the extent of 25 and 50 lbs. per 100 sq. ft., the mesh was completely broken at the cracks. The indications are very strong therefore:

(1) That longitudinal steel up to a certain amount does increase the spacing of transverse cracks and these cracks will open on contraction.

(2) That longitudinal steel above this amount might produce fine transferse cracks, spaced in some cases only a few feet apart.

TEST OF SKEW ARCHES

In the past there have been failures of skew arches generally through excessive stress at the obtuse angle end of the abutment and there are a number of instances of skew arches now constructed which are showing signs of distress at this location. Bridge engineers are in a quandary as to just what constitutes a proper basis for the design of arches in which the abutments are inclined at an angle with the axis of the roadway. A series of tests which is still under way at the Bureau of Public Roads is showing some very striking indications of the wide variation in abutment reactions, both horizontal and vertical, depending upon the angle of skew. Thus far arches have been tested with 60°, 45°, and 30° angles of skew and a 15° arch is now under load. The arches are 7 ft. in span, measured on the center line of the roadway, the ring is 4½-ft. wide at right angles to the center line of the roadway and the rise is one-fifth of the span.

The principal object sought is the determination of the distribution of abutment reactions, both horizontal and vertical, from one end of the abutment to the other. The results obtained on the three arches tested are very clear in showing that by far the greater amount of the load is transmitted to the obtuse angle end of the abutment. In the case of the 60° skew both the vertical and horizontal reactions at the acute angle end are practically zero and there is a straight-line distribution of vertical reaction from the acute angle to the obtuse angle end in all three arches. The more nearly the angle of the arch approaches a right angle, the more nearly uniform does the distribution of both vertical and horizontal reactions become. It would be premature to draw definite conclusions from these tests at the present time but the indications are quite strong that for arches of these proportions the centroid of the vertical and horizontal reactions for a 60° skew is located one-third of the length of the abutment measured from the obtuse angle, and that its location shifts between that point and the center as the angle of skew decreases. The above is a rather rough statement of the indications but a more detailed statement will be forthcoming shortly in a technical paper covering these investigations.

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[5] Reinforcing and the subgrade as factors in the design of concrete pavements, by J. T. Pauls, *Public Roads*, October, 1924, vol. 5, No. 8, p. 1.

Impact Experiments on Bridges

Cooperative impact tests are now being conducted jointly between the Bureau of Public Roads and Iowa State College[6]. Thus far the principal conclusion to be reached is that:

> The accurate determination of impact stresses is now possible with the use of several different types of instruments. It is also possible to measure the force of the blow delivered by motor trucks as influenced by a number of factors, such as bridge floor roughness, deflection, cushioning, etc.

A number of impact stresses have been measured but definite conclusions are hardly forthcoming at the present time.

Earth Pressures on Bridge Abutments or Retaining Walls

The various State highway departments make a wide range of assumptions with regard to earth pressures existing behind retaining walls. A very interesting series of tests has recently been completed in which soil pressure measuring cells have been embedded back of retaining walls during their construction and later, after the fill has been completed measurements of pressure have been obtained. These measurements are quite illuminating and they surely point to the necessity for recognizing the existence of higher earth pressures than are generally thought to exist. One series of tests includes the measurement of pressures back of a bridge abutment some 25 ft. in height. The adjacent stream rises to a considerable height during the spring of the year and the filling material becomes thoroughly saturated and slowly dries out during the summer. The pressure readings in this particular case show conclusively that the pressures increase and decrease in accordance with the percentage of moisture in the filling material which in this case was a clay-loam soil. The pressure varies from that which would be caused by a fluid weighing 44.1 lbs. per cu. ft. to that due to a fluid weighing 29.8 lbs. per cu. ft. It is interesting to note that Rankin's formula for pressure under the assumption of earth weighing 100 lbs. per cu. ft. with an angle of repose of $1\frac{1}{2}$ to 1 gives a pressure equivalent to that of a fluid weighing 28.7 lbs. per cu. ft.

Other tests made on bridge abutments in Washington, D. C., show correspondingly high pressures and the pressure varies with the manner of filling. It is indicated very strongly:

> That provision for draining the fill should be one of the major features of the work which should be carefully designed and executed in the construction of the wall or abutment and that the earth pressure should not be taken at less than that which would be developed by a fluid weighing 28 to 30 lbs. per cu. ft.

Investigations Dealing with Materials of Construction

Among the outstanding investigations made during the past year, from the standpoint of its possible economic importance, is the study of the bulking effect of moisture in sand

Concrete is ordinarily proportioned with the thought that the proportions used will give a certain minimum desired strength and certain desired qualities of workability and density. The general ideas which engineers now have with regard to the strength of concrete are based largely on laboratory tests in which the sand is invariably measured in an air-dry condition. In the field the sand is generally moist and is therefore bulked depending upon its moisture and fineness up to 25% of its air-dry volume. There is little wonder then, that concrete proportioned by volume with moist sand does not have the same characteristics as concrete proportioned in the manner ordinarily used in the laboratory need there be much surprise that field-proportioned concrete, in general, is harsher and does not possess the workability of concrete of the same nominal proportions as made in the laboratory, and, further, it is quite plain why the yield of field concrete is sometimes less than is anticipated.

The bulking tests made during the past year at least point to the desirability of basing the proportions of concrete on the volume of sand as measured in its dry condition. The proportions would then have a much more definite meaning than they have at present, the sand now being measured without regard to its moisture content and condition of bulking. More study should be given to this subject. It has considerable significance. It is interesting to note that proportioning by weight as now practiced in Iowa very largely eliminates the difficulty due to the bulking of sand, but other methods also may be employed.

Investigations of the Characteristics of Aggregates Suitable for Concrete Pavements

One rather extensive investigation, completed during the past year at Arlington, Va., was made primarily for determining the limit of characteristics of aggregates suitable for use in concrete pavement construction. The main question involved was the determination of the minimum standard of quality. To answer this question a number of aggregates were imported from different sections of the country and a concrete-surfaced circular track was constructed with these materials. This track was tested by a special-wear machine, first fitted with rubber tires alone then equipped with tire chains.

The conclusions which have been drawn as a result of these tests are based on three premises:[7]

1. That on the average 18-ft. concrete road, approximately 10% of the total traffic moving in both directions passes over a band 6 in. in width at the point of maximum concentration. Therefore, the traffic passing over the test road should be multiplied by at least 10 to obtain the equivalent volume of traffic on an actual pavement.

2. That the comparative resistance of each test section to the surface wear produced by the tire chains is an indication of the comparative resistance which would be offered by the concrete to wear or disintegration at the edges of exposed joints and cracks under service conditions.

3. That conditions which cause surface wear, such as steel tires, tire chains tracking through snow, etc., are present to such an extent as to make it necessary to give the question of wear consideration in the selection of concrete aggregates.

From the results obtained the following conclusions were drawn:

> That the rate of wear of stone concrete is, in general, not affected by the corase aggregate, provided the coarse aggregate is equal or superior to the mortar matrix in resistance to wear.
>
> That excessive wear will result from the use of very soft stone as coarse aggregate even though used in conjunction with a mortar of satisfactory quality. From the results of these comparative tests, it would appear that stone with a percentage of wear over seven should not be used in concrete road construction.
>
> That gravel concrete, in general, is at least as satisfactory from the standpoint of wear as stone concrete.

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[6] Impact tests on highway bridges, *Public Roads*, September, 1924 vol. 5, No. 7.

[7] Wear of concrete pavement tested, by F. H. Jackson and J. T. Pauls, *Public Roads*, May, 1924, vol. 5, No. 3, p. 1.

That gravels consisting essentially of siliceous materials are superior as regards both the amount and uniformity of wear to those containing a preponderance of calcareous fragments.

That gravels consisting of rounded particles are as satisfactory from the standpoint of wear as those consisting either wholly or in part of angular or crushed fragments.

That small amounts of shale occurring in the coarse aggregate will cause both excessive and uneven wear.

That the modified abrasion test for gravel in its present form is not an indication of the wear-resisting properties of coarse aggregates. It is suggested that if the severe impact action of the steel balls were decreased, much more indicative results would be secured.

The blast furnace slags should prove satisfactory for use on concrete pavements provided the proportion of light, porous slag is so controlled that the weight per cubic foot will be at least 70 pounds.

That the presence of large amounts of light, porous fragments in blast furnace slag will cause excessive wear.

That somewhat better results are secured by the use of the smaller sizes of slag.

That slag or stone screenings are, in general, unsatisfactory as substitutes for natural sand as fine aggregate in concrete road construction.

That the copper and lead smelter slags used in these tests would make satisfactory aggregates for concrete road construction from the standpoint of wear.

That coarse sands, other things being equal, show greater resistance to wear than fine sands.

That the so-called "tensile-strength-ratio" test is no indication of the wear-resisting properties of concrete made with these sands.

That the Talbot-Jones wear test is not, in general, an indication of the wear which takes place under traffic.

That neither the crushing nor the transverse strength of concrete is a measure of its wear-resisting properties.

That the addition of hydrated lime in the proportion used in these tests does not affect the wear-resisting properties of concrete.

That so far as resistance to wear alone is concerned, increasing the cement content beyond a cement-sand ratio of 1:2 does not materially affect the concrete. Leaner mixes on the other hand show marked increase in wear.

That unusual precautions should be taken in using mine chats or other similar harsh-working materials, so as to increase workability to a maximum and thus make possible a smoother surface finish.

That, other things being equal, either an excessively dry or an excessively wet mix will show less resistance to wear than concrete of medium consistency.

A number of other tests are under way covering a wide variety of subjects having to do with both materials and design. From these researches, indications and definite conclusions are gradually being drawn. All of these investigations should be of interest to the highway engineer. They involve such tests as fatigue of concrete, the effect of calcium chloride curing on concrete, investigations of bituminous materials, the study of the laws governing the stability of bituminous mixtures, causes of scaling of concrete roads, and a large number of other problems, each having an important bearing on the production of better and more economical pavements and structures.

Interesting Form Details

Some interesting methods were employed to save time and insure the proper handling of forms in the construction of the new Atlantic warehouse for the Atlantic and Pacific Tea Co., in Detroit, Mich., by the Turner Construction Co. The building, described in the *American Contractor* as a 5-story building covering a ground area 105 ft. x 273 ft., was erected with one set of forms. Unusual details in handling the forms included specially arranged braces and ropes for lowering floor panel forms; a method of fastening form braces to the concrete floors with the aid of nuts placed in the green concrete of the floor; wooden shoring for exterior concrete beams, the extended exterior member of the shore acting as a brace against which the outside panel of the beam form was wedged.

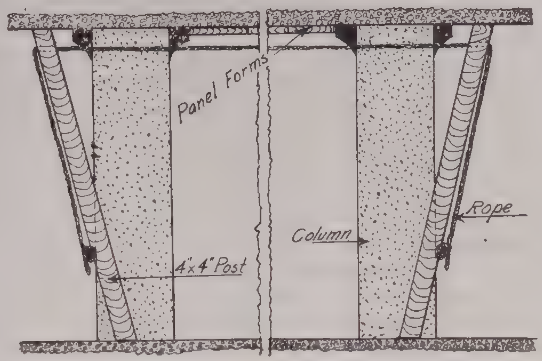

Fig. 1—Arrangement of 4 inclined posts and 2 ropes used for lowering floor panel forms

Fig. 1 shows the efficient device used for lowering floor panel forms by which all smashing of forms was eliminated when the sections were taken down. The use of this device involved the placing of four heavy posts each about 8 in. longer than the distance between the floors with the upper end of each post slanting away from the floor panel as shown in the illustration. A hole was bored near the top of each brace through which a heavy rope was passed and carried down to a snubbing cleat nailed to the brace near the bottom.

In lowering a panel, the braces were first put in place, the rope passed through the holes with the ends fastened to the cleats. This provided two parallel rope lines across the space beneath the panel so that when the panel dropped from the floor above, it was caught on the two ropes and lowered by the slacking away of the rope on the cleat until the floor was reached. After being removed in this manner, the panels were trucked and hoisted to place for use on the next floor.

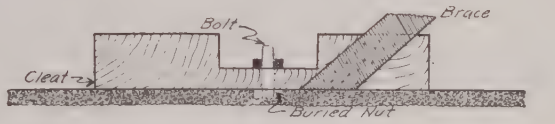

Fig. 2—Simple and efficient method of fastening nailing cleats to concrete floor with the aid of threaded nuts embedded in the concrete at the time it was poured

In order to prevent tearing up the green floor, as would

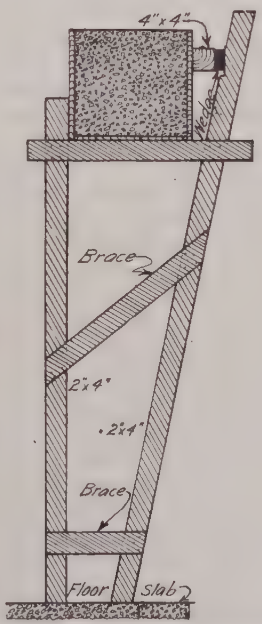

Fig. 3—Combined wooden shore and form brace for supporting outer beam panel on exterior beams of warehouse

have been the result of nailing scrap pieces of wood to the top of the green concrete floor to which to brace the column forms, threaded nuts were embedded in the surface of the concrete at points opposite the location of the columns and at a proper distance from the column base to give adequate bracing. These nuts were placed at the surface when the concrete was poured. This arrangement is illustrated in Fig. 2. A bolt threaded on each end was screwed into the nut and a notched and drilled cleat forced over each bolt and fastened down by the tightening of the top nut. This provided a good anchorage for the bracing and the cleat could be easily removed when the bracing was no longer necessary, the embedded nut being left in the floor.

The combination shore and side bracing shown in Fig. 3 was devised to insure perfect forms for the exterior beams of the building and to prevent any bulging of the exterior side panels. As shown in the accompanying illustration, each shore was made of 2-in. x 4-in. pieces, one being a couple of feet longer than the other to allow it to be inclined and to extend up above the top of the outer forms for the exterior beams. The top brace nailed horizontally supported the bottom of the beam form. Other braces were formed as shown in the illustration and both ends of the shoring were braced against the floor below.

The section of the scantling which extended outside and above the beam was utilized as a brace against which the outer form was wedged to prevent the bulging of the form as the concrete was poured. In each case this upper end was notched and short 4-in. x 4-in. timber placed along the side of the form and securely wedged between the end of the projecting shore and the beam panel.

This work was carried out under the direction of H. C. Pope, superintendent of the Detroit job for the Turner Construction Co.

Shall Anything Be Added to Portland Cement?

By Maximilian Toch
Vice-President Toch Bros., New York City

Abstracted from a paper presented at the 21st Annual Convention of the American Concrete Institute, Chicago, Feb. 24-27, 1925.

Exhaustive laboratory experiments covering a period of years on the correct treatment to use in portland cement structures to relieve the gray, somber, monotonous appearance without interfering with the setting or with the tensile strength of the concrete led to the following conclusions:

Certain pigments including ordinary Venetian red or any red oxide containing calcium sulfate is dangerous as a mortar color.

Chrome yellows and copper greens are not to be used as they detract from the lime.

It is more important to paint reinforcing rods either with an alkali-proof paint or with a wash of pure portland cement than it is to let them go uncoated. The popular fallacy that rusty iron adheres to concrete is an error as is shown by the experiments.

Where calcium chloride is used as an anti-freeze or some other of the basic chlorides, they are likely to rust steel in spite of the excess lime that may be in the concrete. It is therefore essential to paint with an alkali- or chloride-proof paint and in that case, a simple wash with concrete is not sufficient.

It was found that the reasonably priced blue-green or green, that would most naturally appeal to most chemists, being a carbonate of copper or some other insoluble salt of copper, practically destroyed the tensile strength of blocks of concrete in which they were used. It was found that no color is useful in portland cement which combines with lime for in combining with the lime, it prevents the cementitious quality of the cement itself and what really takes place is, that instead of the lime liberating and crystallizing thereby forming a reticulated structure which bonds the small particles of aggregate together, the lime is transferred where a copper pigment is used, into a copper lined compound with disastrous results to the ultimate strength of the concrete structure.

Many portland cement manufacturers do not hesitate to recommend as much as 9% of a certain pigment and yet will not permit the addition of one or two percent of material designed to improve the concrete. In conducting experiments on integral waterproofing, the writer found that much more than 2% of various materials might be added to cement which would decorate and at the same time increase the physical qualities of portland cement. As a general rule, a pigment that does not combine with lime while it is being generated, produces in itself a tensile strength which is quite remarkable. In the case of certain blue pigments, an enormous increase in tensile strength results but these are not recommended for use either as waterproofing or wear-proofing material because of a decidedly blue tone of the resulting concrete. Investigation shows that an additional amount of an aluminate has probably been formed which in itself is a cementitious material.

In the case of certain dark gray pigments the increase in tensile strength is due to the addition of calcium phosphate, but certain yellows and greens are not to be recommended on account of their abnormal reduction and for the further reason that pigmented concrete is soluble in water. *A pigment added to portland cement must not be soluble.*

There has been a lack of cooperation between chemical engineers and concrete engineers as ordinarily the concrete engineer has not regarded portland cement and its reaction in any other light than that of a physical cementitious material which needs little or no explanation. Portland cement is a chemical compound and its reactions are purely chemical and while there is a general concensus of opinion that concrete properly made needs no integral or surface treatment for waterproofing or hardening, there are many cases where the treatment of concrete either before it is finished or after is essential. Concrete in a chemical works requires, in most cases, the addition of an integral compound or the application of a coating material to preserve it against acid or alkaline decomposition. Instances cited where the surface should be treated to prevent frost cracks, surface disintegration, dusting, etc., include concrete roadways and floors in the interior of buildings.

While concrete may be made which, in itself is permanent, without the addition of anything, the lasting qualities of portland cement alone cannot be depended upon in chemical engineering work. Admitted that there are many cases where portland cement must be treated either during or after its construction, there is no one panacea which covers it all.

Corrosion of Steel in Concrete

When steel corrodes its volume increases in relation to its molecular weight and the increase is as 112 is to 211. This varies with the nature of the corrosion. Yellow rust is taken as a standard. Investigations made by the writer led to the conclusion that rust was not definitely the trihydroxide of iron $Fe_2O_3\ 3H_2O$, but it would be a magnetic form of black and it could also be the brown variety containing less water than the yellow. The increase in volume when the rust forms produces pressure so that if rust starts underneath a film of paint, the increase in the volume of rust as compared with the steel itself lifts off the film of paint. It is a well-known law in physical chemistry that any reaction that produces pressure is retarded by pressure.

Tradition has taught that concrete prevents corrosion of steel and progress is retarded on account of tradition in many instances. If a steel bar is embedded in concrete sufficiently deep and kept back from the exterior face sufficiently far so that the weight of the concrete is greater than the pressure produced by corrosion, no corrosion will result. If the bar is sufficiently near the surface so that the action of water and air can reach the steel, there will be corrosion and the pressure produced by it splits the surface off the concrete. The general statement therefore, that concrete prevents corrosion is not correct. Concrete may accelerate corrosion if the amount of lime liberated is below a given strength.

If a piece of bright clean steel is embedded ¼ in. below the surface of a piece of concrete, the test specimen can be submerged in all kinds of corrosive liquids and no corrosion of the steel takes place, if the concrete is mixed one part portland cement and two parts sand. A 1:2 mixture sufficiently trowelled is impermeable, and the amount of alkali generated by a rich mixture of that kind is sufficiently great to prevent corrosion. If a steel bar is embedded in a 1:2½:5 mixture, corrosion will result or it can be prevented by increasing the distance that the steel is from the surface.

Reinforcing rods can be painted with a mixture of neat portland cement and lime water so as to insure a percentage of alkalinity beyond the corrosive point and any one of the good mixtures on the market composed of zinc and magnesium fluosilicate which would precipitate enough silica into the pores of the concrete to prevent moisture getting through would make the surface frost proof. There are two elements that produce rust, one is air (oxygen) and the other is water. Pure air contains no water and is non-corrosive and distilled or boiled water that contains no air is also non-corrosive. Unless the surface of the concrete is waterproofed or the bars treated so that they will not corrode, if they are placed near the surface to obtain the greatest strength, serious damage to the concrete will result. Where a cement wash is used as an exterior finish for an added protection on a concrete building, the cement in the wash may or may not set and if it does not, a simple coating of dust will result.

In regard to the disintegration of concrete in sea water, the simplest theory advanced as to why concrete will not hold in sea water is the solubility of lime in pure water and its greater solubility in salt water. In the construction of the dry dock No. 4, for the United States Navy, every part of it was waterproofed excepting the bottom. This bottom which is many feet thick and was carefully laid is not in good condition in spite of considerable repair work that has been done upon it, while the side walls which were waterproofed are in perfect condition.

There are many good materials on the market which should be used for coloring cement, waterproofing cement, lubricating concrete and protecting it against acid and alkaline conditions which normally destroy concrete, and the same liberal interpretation for the use of added materials to increase the utility of concrete and concrete structures is much to be desired.

Notes on Laitance

By R. M. Miller

Abstracted from a paper presented at the 21st Annual Convention of the American Concrete Institute, Chicago, February 24-27, 1925.

Although the formation of laitance in pouring concrete both under water and, in a smaller measure, in the dry has been regarded by many construction engineers as one of the inevitables like death and taxes, it can be controlled under water and the formation should not be allowed to go to a point injurious to the concrete. Inasmuch as slime or laitance takes from the mix cement, particularly the finest particles from which the concrete derives its greatest cohesiveness, a study of the causes and a remedy as carried out in connection with the pouring of 3,900 cu. yds. of the seal concrete under water in the steel caissons of foundations recently constructed for the Virginia Railway Coal Pier No. 2 at Sewall Point, Va., is of value.

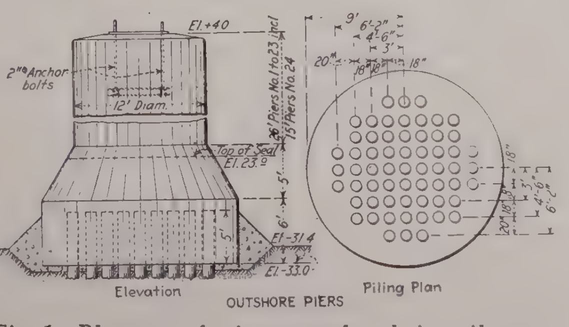

Fig. 1—Placement of caisson over foundation piles

The bottom of the bay at the site of the pier is of sand, clay and shells, overlaid with a blanket of mud or silt varying in depth from several inches to several feet. The foundations were constructed using steel forms placed over piles as shown in Fig. 1. After the cylinders were placed, they were tested for mud and where more than two or three inches was found it was pumped out. Gravel was spread over the bottom to a depth of approximately 6 in. and 1:2:4 seal concrete was poured with the aid of a bottom-drop bucket, at the rate of 90 cu. yds. every six or seven hours. During this time, the cement-bearing water within the saisson was agitated continuously. After the seal concrete had set for four or five days, the water was pumped out and the laitance which varied in depth from several inches to several feet was mucked out so the concrete could be picked rough and thoroughly scrubbed before continuing the concrete in the dry.

MATERIALS AND METHODS

Coarse aggregate used in the pier foundations was of excellent quality, well graded, bank-run gravel from ¼-in. to 2-in. The fine aggregate was a sharp coarse beach sand, testing 4% silt and practically no organic matter. A carefully inspected 1:2:4 mix was made using Atlas cement showing a residue on a 200-mesh sieve of 17%, the time of mixing being from 2 to 3 min. A relative consistency of about 1.25 corresponding to a slump of 6 in. was used first and was later changed to about 1.10 corresponding to a slump of 2 in. to 3 in. This reduction in the water ratio being an important factor in cutting down the amount of laitance developed.

A 1½-cu. yd. open top, bottom drop bucket was used for depositing the seal concrete. The bucket was invariably full of concrete when lowered. Close supervision was given the speed of lowering and retrieving the bucket and to its position when discharged, the improved manipulation of the bucket by the derrick operator effecting a considerable decrease in laitance. The somewhat too hurried lowering and raising of the bucket and occasional premature tripping of the bottom drops in the early stages of this construction was the most important factor in the development of the laitance during that stage of the work.

Causes of Laitance and Analyses

An unavoidable element contributing to the formation of laitance was the 5-ft. drop of the concrete through the water at the beginning of the pouring of the seal, caused by the foundation piles.

Samples were taken from the top and bottom of the deposit of laitance, as the work progressed. The dried and hardened laitance was subjected to chemical analyses but no marked difference was found between its chemical constituents and those of the cement used on the work. The following analyses indicate that the chemical constituents of the laitance vary no more from those of Atlas cement than those of one standard brand of cement vary from another.

	Laitance	Atlas Cement Used on the Work	Standard Portland Cements—Hand Book Reference
Moisture	7.55		...
Silica (SiO_2)	22.49	21.31	19.06
Iron (Fe_2O_3) and Alumina (Al_2O_3)	7.56	6.84	9.76
Calcium Oxide (CaO)	62.40	62.80	61.23
Magnesium (MgO)	Trace	2.64	2.83
Sulfuric Acid (SO_3)	Trace	1.34	1.34

The laitance was found to be of a chalky color, hardening slowly, with a specific gravity of 0.69 of sufficient buoyancy to float until water-soaked. It appears to be a mechanical mixture of the finest particles of cement and a little fine sand and silt from the bottom. When put through a No. 200 sieve and remixed with water, a whitish mortar is formed, smelling strongly of lime.

From data covering the entire volume of the work an approximate percentage of cement in the laitance was determined to be 13.2%. If the loss in tensile or compressive strength were merely what should be expected from the loss of richness of the mix, the loss could be easily remedied by an additional allowance of cement. As the loss is of the fines of the cement, it is a more serious matter.

Cement and Laitance Tests

Cement is composed of a gradation of particles from an impalpable dust to a comparatively coarse clinker. Of this mixture the clinker or coarse particles are comparatively inert and only the finer particles or dust have quickly setting or binding characteristics, being therefore the most valuable portion of the cement. Taken separately, neither dust nor clinker is effective, but taken together, a balanced mixture is formed. The dust in water forms laitance, while the clinker in water forms a weak mortar. If the two portions of the cement are removed, the greatly improved mixture results.

Observations and Suggestions

Laitance, as has been pointed out, varies in chemical constituents from those of the cement used on the work no more than one standard brand of cement varies from another. It therefore seems unlikely that any chemical reaction or crystallization of importance takes place between sea water and the cement of the concrete during the pouring or during the four or five days that the laitance has remained immersed. In the mind of the writer the suspicion has lingered that the chemical constituents of sea water are responsible in some measure for excess formation of laitance in under water concrete. While this suspicion is strengthened it has been by no means confirmed.

Bates, Phillips and Wig, in *Technologic Paper No. 12* of the Bureau of Standards, have shown that 1:2:4 concrete of Jersey sand and trap rock of a consistency called "quaking or mushy" when placed by a 5-in. tremie under fresh and sea water develops in fresh water at four weeks, three times the compressive strength of that poured in identically the same manner under sea water. Quite evidently something of importance takes place between sea water and the cement of under water concrete during the first weeks. On account of the conflicting views as to the behavior of cement in sea water it is not the intention of the writer to suggest the addition to the cement of siliceous materials or the use of special cements, but rather improvement through better protecting the plastic mass of concrete from contact with fresh or sea water by more careful methods of placing.

The formation of laitance withdraws from the concrete by wash the fines of the cement. It is extremely doubtful if the concrete placed by bottom drop bucket or tremie is so affected throughout its mass. It is highly probable that only the outside of the concrete charge is so affected and that the resulting concrete consists of masses of dense concrete between which will be found pockets or layers of concrete of much greater porosity. If the amount of permeability of the concrete is responsible for the rate of disintegration by the action of the salts of sea water and of the alkali waters of the West, it follows that the presence of layers or pockets of lean concrete or of laitance or construction seams invite failure. It is therefore of the greatest importance that the formation of laitance be held to a minimum. In the case of the Virginian Railway Pier No. 2 the steel caissons were left in place after completing the foundation. This is a very effective protection against the action of the sea water.

Whether or not any chemical reaction of importance occurs between the salt water of Hampton Roads and cement in the formation of laitance, the condition of the mix and the wash is in large measure responsible. It is mainly a question of manipulation. Laitance can be held to minimum by the following:

(1) Use a clean aggregate.

(2) Make the bottom as free of mud as possible.

(3) Use fresh water in the mix, free from dirt, earth or sewage.

(4) Cut off all high piles that have driven to refusal. Hold the penetration of the foundation piles into the concrete to a minimum for stability.

(5) Use mix of a relative consistency of from 1:10 to 1:15 and use the slump test to keep the consistency uniform.

(6) Leave the bottom drop bucket open at the top but with bottom doors that open freely downward when tripped. Fill the bucket completely with concrete before being slowly lowered. When discharged the bucket should be returned slowly until clear of the concrete. The installation on the bottom of the bucket of an automatic trip so arranged that the bottom drops cannot be released until the trip has touched pile heads or concrete. If metal top doors are to be used they should preferably rest upon the charge of concrete when the bucket is full and open downward and follow the concrete as it is emptied. If the usual top doors resting upon the rim of the bucket are to be used it should be so arranged that they can be opened slowly upward before the charge is emptied.

(7) If the arrangement of the foundation piles and the shape and dimensions of the foundation caisson are such that the tremie can be used to advantage it is preferable to the bottom drop bucket, in the writer's opinion, provided the nose of the tremie is kept below the surface of the concrete already placed and the pipe is continually full of concrete. Every charge lost means additional laitance.

In passing it should be added that retempering of concrete has also been found of advantage in the elimination of laitance. This process consists in mixing concrete and storing for several hours during which time the initial set takes place. It is then returned to the mixer and remixed without the addition of water. Concrete retempered inside of two or three hours gains slightly in strength, hardens much more rapidly, will show no shrinkage after being placed in the dry, or swell when poured under water, and will not lose the fines of the cement through wash to any appreciable extent. English engineers extend the time of retempering to as much as five hours. Retempering of concrete on work of any magnitude in this country is of somewhat doubtful value as the time lost in storing and remixing is an important factor. The cost of furnishing either the necessary hopper cars and track for three hours' storage or the construction of bins, chutes and an elevator or any other storage device would necessarily be reflected in the unit cost per cubic yard to such an extent as to make the plan on many jobs unacceptable.

The application of corrective measures to the pouring of the under-water concrete for the Virginian Railway Pier No. 2 effected a marked improvement. Whereas on the extreme inshore end of the pier the formation of laitance reduced the mix from 1:2:4 to 1:2:.8:5.6, on the outboard end of the resulting mix averaged 1:2.2:4.4. In short, if laitance develops either in under-water concrete or concrete poured in the dry the cause is too much water either in the mix or added to the concrete in placing.

Calcium Chloride in Concrete

By Duff A. Abrams

Professor in Charge, Structural Materials Research Laboratory,
Lewis Institute, Chicago

A condensed summary of a paper before the American Society for Testing Materials, to appear in full in 1924 Proceedings.

Introduction

The use of chemical compounds for hastening the hardening of portland cement concrete has attracted considerable interest during the past few years. Experience and earlier tests had shown that calcium chloride, or materials having this compound as one of their principal constituents, was probably the most promising for this purpose. Early in 1921, investigations on the effect of chemical admixtures on the compressive strength were begun by the Structural Materials Research Laboratory, Lewis Institute, Chicago, in cooperation with Committee C-9 on Concrete and Concrete Aggregates, of the American Society for Testing Materials.[1]

Scope of Tests

The tests carried out at Lewis Institute covered a much wider range than originally outlined by Committee C-9. They included tests of concrete at different ages for a wide range in mix, consistency, and curing, using different percentages of calcium chloride and other chemical admixtures. A few tests were made using calcium chloride in concrete mixed and cured at low temperatures. Three separate investigations covering about 7500 strength tests of concrete and mortar were carried out.

Materials and Methods

All tests were made with portland cement purchased in Chicago. The aggregate for concrete consisted of sand and pebbles from Elgin, Ill., graded 0 to 1½ in. The mortar tests were made with Elgin sand graded 0 to No. 4.

Six different admixtures were used:

Calcium chloride A } Samples from different manufacturers
Calcium chloride B }

"Cal" (standard and low chlorine Cal) furnished by Cal Chemical Co., Hagerstown, Md.

"Vitriflux," furnished by the Granitex Co., New York City.

Magnesium chloride, purchased in Chicago.

The commercial calcium chlorides were obtained from different manufacturers and contained about 75% of $CaCl_2$, with small amounts of impurities.

Two lots of Cal, standard and low chlorine, were used. The material comes as a white powder. The standard contained about 25% of calcium chloride, or about 16% chlorine; the low-chlorine Cal contained 14% of calcium chloride, or 11% of chlorine.

Vitriflux is a solution of calcium chloride in water (about 34% of $CaCl_2$).

The magnesium chloride was of the grade commercially known as "flake," and contained about 46% of $MgCl_2$.

Test Pieces

The concrete specimens were 6 x 12-in. cylinders and the mortar specimens were 2 x 4-in. cylinders. The specimens were made in accordance with the standards of the American Society for Testing Materials.

The concrete cylinder forms were of cold-drawn steel tubing, slotted along one element. In making the specimens, the forms were placed on machined cast-iron plates. The concrete was placed in 3 layers, each layer being rodded 30 times with a ⅝ in. bullet-pointed steel rod. The specimens were capped 3 to 4 hours after molding with neat cement (which had been allowed to stand 3 to 6 hours after mixing) and the caps brought to a true plane by means of machined plates which were worked down to the tops of the forms and left in place until the forms were removed after 16 to 20 hours.

In general, each concrete specimen was made from a batch of about 1-5 cu. ft., proportioned separately and mixed with a bricklayer's trowel in a shallow metal pan. The proportions of cement and aggregate were expressed as one volume of cement to a given number of volumes of dry, rodded aggregate mixed as used. In a few tests, the concrete was mixed with shovels on a metal plate in batches of sufficient size to make seven 6 x 12-in. cylinders.

The mortar specimens were of 1 : 2½ mix by volume.

The plasticity of concrete measured by means of the "flowtable" using fifteen ½-in. drops in 10 seconds. For relative consistency 1.00, sufficient water was used to give a flow of about 180. This represents a consistency such as would be used in machine-finished concrete road construction and corresponds to a slump of about ½ to 1 in. For a relative consistency of 1.10, 10% more water was used than for relative consistency 1.00; similarly for other consistencies.

In general, the specimens were cured in a room in which the air was saturated with moisture and in which a uniform temperature of about 70° F. was maintained. In certain tests, specimens were cured in a moist room for part of the curing period and the remainder in air of laboratory. Tests were also made on specimens cured in air of laboratory and outdoors exposed to low temperatures for the first few days.

In general, the conclusions are based on average strengths of 8 to 10 concrete specimens or 5 mortar specimens made on different days.

Discussion of Tests

These investigations were primarily tests on the effect of admixtures of commercial calcium chloride and of similar materials on the *compressive strength* of concrete made and cured under *normal temperature conditions*. A few tests were made at temperatures near freezing. However, in view of the limited number of tests at low temperatures the results should not be considered as a comprehensive study of the value of calcium chloride in concrete work carried out in cold weather.

The investigations did not cover the curing of concrete by spreading calcium chloride over the surface; nor were any tests made to determine the merits of so-called "floor hardeners."

In studying the effect of the various admixtures under the different conditions of test it is convenient to compare the strengths obtained with the strength of similar concrete without admixture. The percentages computed on this basis are the "strength-ratios" and express the strength as a percentage of the strength of plain concrete identical as to age, mix, consistency, brand of cement and curing. The "maximum strength ratios" are the highest values shown by the curves representing the variation in strength due to the amount of admixture for a given set of conditions.

Fig. 1 shows the relation between amount of calcium chloride and compressive strength for 5 different concrete mixtures and Fig. 2 the relation between strength and age for

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[1] For report on other tests on accelerators made by Committee C-9 see page 223, 1923 Proceedings, American Society for Testing Materials.

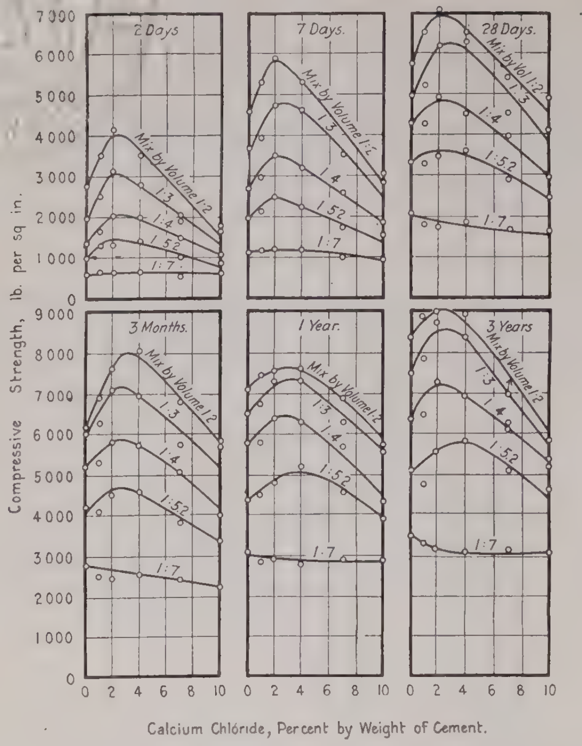


Fig. 1—Effect of Calcium Chloride on the Strength of Concrete as Influenced by Mix

Compression tests of 6 q 12-in. concrete cylinders cured in moist room.
Each value is the average of 5 tests made on different days.
Calcium chloride *B* was used.

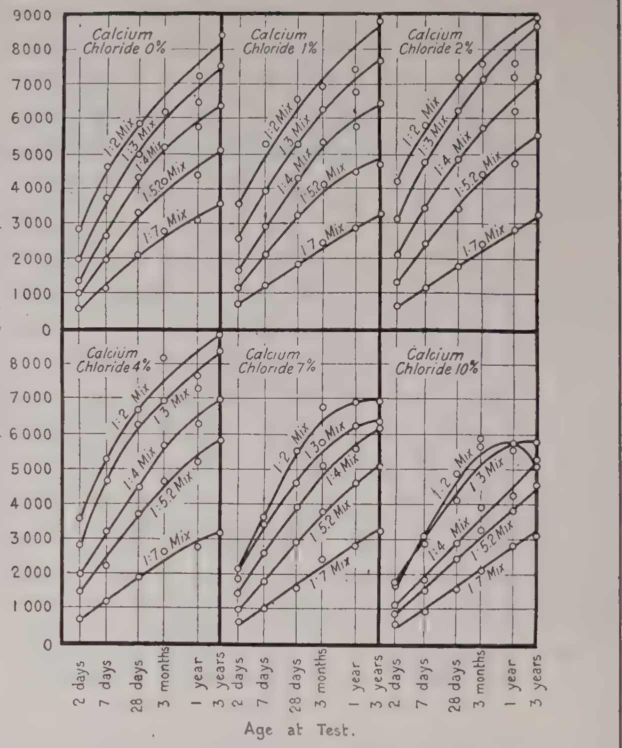


Fig. 2—Effect of Age on the Strength of Concrete

Compression tests of 6 x 12-in. concrete cylinders cured in moist room.
Age plotted to logarithmic scale.
Relative consistency 1.00.
Calcium chloride *B* was used.
Each value is the average of 5 tests made on different days.

5 different mixtures and 6 percentages of calcium chloride. The effect of 2% of calcium chloride by weight of cement on compressive strength at different ages for 3 concrete mixtures of relative consistency 1.00, and for a 1:5.2 mix of relative consistency .90, 1.10, 1.25, and 1.50 is shown in Fig. 3. Complete details of concrete tests using other mixes, consistencies and other cements are not given.

The principal conclusions from the tests are:

1. Calcium chloride and the admixtures containing calcium chloride when used within certain limiting percentages, gave increased strength to concrete.
2. Magnesium chloride in flake form (46% magnesium chloride, 54% water) when used in concrete caused a reduction in strength except for small percentages, which showed a slight increase for 2 and 7-day tests.
3. The effect of the calcium-chloride admixtures in concrete varied with the type and quantity of admixture. When the tests are compared on the basis of chlorine content the different admixtures give similar results but not the same numerical values.
4. Calcium-chloride admixtures of the types used increased the strength of concrete approximately in proportion to the amount used up to a certain "optimum" percentage; the strength increase became less for further additions. Beyond a certain "critical" percentage further additions produced a reduction in strength as compared to similar concrete without admixtures.
5. Optimum and critical percentages for the calcium chloride admixtures used in these tests for 1:5.2 concrete of normal consistency and cured in moist room, were as follows:

Admixture	Per Cent of Admixture by Weight of Cement		Per Cent of Chlorine by Weight of Cement	
	Optimum	Critical	Optimum	Critical
Commercial Calcium Chloride A...	2 to 4	6 to 8	1 to 2	3 to 4
Commercial Calcium Chloride B...	2 to 4	6 to 8	1 to 2	3 to 4
Standard Cal....................	7 to 10	15 to 20	1 to 2	3 to 4
Low Chlorine Cal................	about 10	15 to 20	1 to 2	2 to 3
Vitriflux.......................	6 to 8	10 to 15	1 to 2	2 to 3

6. The relative effectiveness of the different admixtures when compared on the basis of strength-ratio (the ratio of the strength of concrete containing admixture to that of similar concrete without admixture, expressed as a percentage) for the optimum percentages, is shown by the following strength-ratios, which are based on tests of 1:5.2 concrete of normal consistency cured in the moist room:

Admixture	Strength-Ratio for Optimum Percentage					
	2 days	7 days	28 days	3 mo.	1 yr.	3 yr.
Commercial Calcium Chloride A	170	125	110	112	117	118
Commercial Calcium Chloride B	147	124	109	109	119	116
Standard Cal.................	151	123	107	107	121	119
Low-Chlorine Cal.............	143	118	101	104	113	111
Vitriflux....................	138	115	106	108	109	114

7. The addition of calcium-chloride admixtures in amounts less than the "critical" percentage produced an increase in concrete

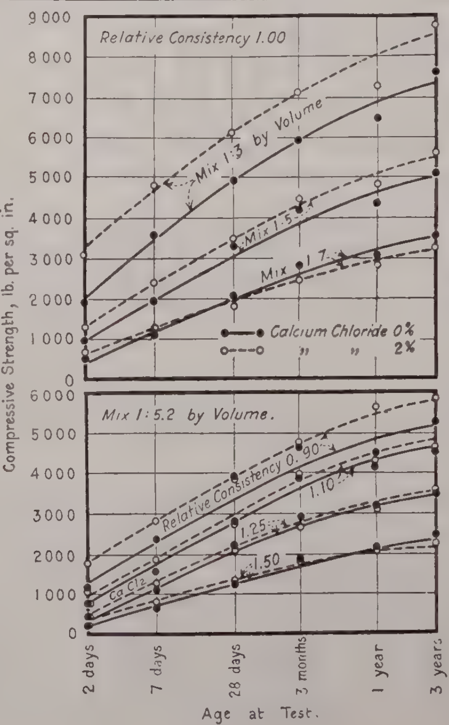


Fig. 3—Effect of Calcium Chloride on the Strength of Concrete as Influenced by Age at Test

Compression tests of 6 x 12-in. concrete cylinders cured in moist room.
Age plotted to logarithmic scale.
Calcium chloride *B* was used.
Each value is the average of 5 tests made on different days.

strength that was practically constant at all ages. This constant strength increase, when expressed as a percentage of the strength of concrete without admixture, showed a diminishing ratio as the concrete gained in strength with age.

8. The addition of 2% of calcium chloride to 1:5.2 concrete of the consistency ordinarily used in construction work (1.10 to 1.25) produced an increase in compressive strength of 100 to 200 lb. per sq. in. at ages of 2 days to 3 years; for 1.50 consistency there was little or no increase; for consistency 0.90 the increase was about 550 lb. per sq. in.

9. The increase in strength due to the addition of 2% of commercial calcium chloride was practically negligible for a 1:7 mix; it increased with the cement content up to about a 1:4 mix; for mixes richer than 1:4 the strength increase remained about the same. The strength increase for the different mixes and the corresponding strength-ratios for ages of 2 days to 3 years were as follows:

Mix	Strength Increase, lb. per sq. in. (same for all ages)	Strength-Ratio, per cent (Fig. 4)				
		2 days	7 days	28 days	3 mo.	3 yr.
1:7	Negligible (±100)	115	107	85	88	95
1:5.2	400	138	125	107	110	110
1:4	700	148	130	119	117	115
1:3	1200	150	130	122	119	115
1:2	1300	149	130	122	120	105

10. The tests confirm the relation between water-cement ratio and compressive strength pointed out in other publications of this laboratory. The water-ratio-strength curves for 2% of commercial calcium chloride were similar in form to those for plain concrete but divergent at the lower water-ratios, showing the greater effect of the calcium chloride on the richer mixes and drier concretes.

11. The effect of commercial calcium chloride on the strength of concrete cured under different moisture conditions at normal temperatures was slightly greater in concrete cured in the air of the laboratory than in concrete cured in water or in the moist room.

12. For concrete cured outdoors at temperatures near freezing, the use of 3% of calcium chloride produced about the same strength increase as for other curing conditions. This strength increase appears as a much higher percentage gain when compared to the low strengths attained for outdoor curing. Too much dependence should not be placed on the use of calcium chloride for preventing freezing of concrete in cold weather; common salt should not be used for this purpose.

13. The cements used in the tests were in general similarly affected by addition of calcium chloride.

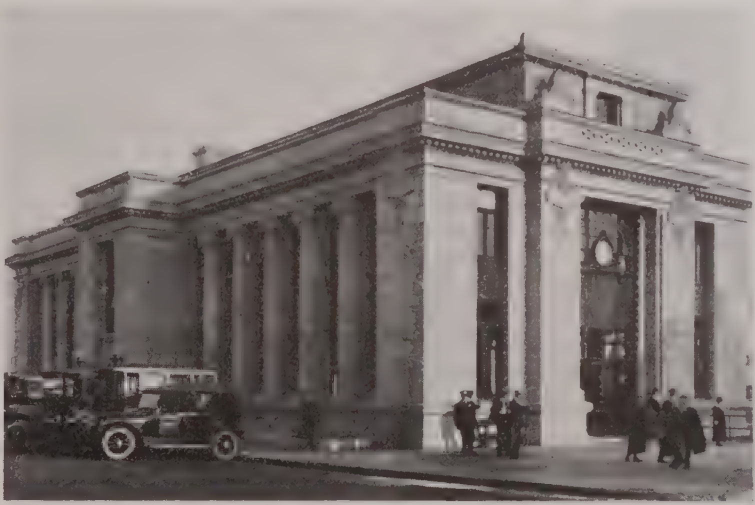
14. The effect of calcium chloride in mortar was essentially the same as in concrete.

15. The time of setting of the cement used was shortened by each of the admixtures. Flash set was produced by most of the admixtures when used in percentages somewhat in excess of those found to give greatest strength increases in concrete.

16. The important conclusion from these tests may be summarized as follows:

In the use of calcium chloride no advantage was gained for percentages of the commercial product greater than 2 or 3% of the weight of cement; (chlorine content 1 to 1½%). This amount when used in mixes of about 1:5 and in consistencies suitable for building construction showed an increase in compressive strength of from 100 to 200 lb. per sq. in. which increase was practically constant at ages of 2 days to 3 years. For richer mixes and drier consistencies the strength increase was greater and for leaner mixes and wetter concrete it was less.

Handsome Cast Stone Structure



Latest Addition to Victoria's Waterfront Architecture

"One of the most artistic structures of its kind in the Dominion" is the way one noted architect expressed his opinion of the new marine terminal building of the Canadian Pacific Railway liners at Victoria, B. C., shown in accompanying illustration. It is surfaced entirely with cast stone. Wide pylons flank the two principal facades and the Ionic columns are surmounted by a bold cornice and entablature. The building is a distinct acquisition to Victoria's waterfront —already made architecturally very beautiful by the provincial legislative building and the Empress Hotel.

The new Victoria terminal building is 122 x 54 ft., three stories high, with a fourth story 122 x 25 ft., superimposed centrally over the main structure. The construction is of reinforced concrete, surfaced with 15,500 cu. ft. of cast stone, manufactured on the site by the Dawson Art Stone Works. By producing the cast stone on the site, expensive freight and handling charges from the company's factory at Vancouver were avoided. Some four and a half months were required to produce the stone.

The facing, which is one inch in thickness, is composed of a mixture of white and grey portland cement, granite and marble particles, proportioned for maximum density. The natural aggregate colors were blended to produce a shade similar to that of Haddington Island stone, which was used in the parliament buildings nearby, and which is well known and much favored by local builders. The backing of the cast stone blocks is of ordinary concrete, 1:4 mix.

As a result of the fine appearance produced by this building, cast stone has come into immediate favor in Victoria and vicinity, particularly since a comparable grade of natural stone, Haddington Island, Newcastle Island or other loca sources costs considerably more money, representing expensive moving and cutting operations. In the Canadian Pacific marine terminal building, which cost $200,000, the saving by the use of concrete stone was estimated at $80,000.

The architects for this building were Rattenbury and James of Victoria, well known in British Columbia and on the Pacific Coast. Luney Brothers of Victoria were the contractors.

Granolithic Floor Surfaces

By *A. B. MacMillan*
Chief Engineer, Aberthaw Company, Boston

This article on Granolithic floor surfaces is from a very interesting publication issued by the Aberthaw Co., Boston, entitled *Factory Floor Surfaces.* The book, 6x9 in., bound in board, contains 34 pages and discusses the merits and demerits of floor surfaces for different factory uses.

Granolithic finish, as commonly used for floor surfaces, is of the same general nature as structural concrete, that is, a mixture of stone, sand and cement. The proportion of these materials is different and because of the importance of a floor surface, greater care must be used in the selection of materials and in mixing, placing and finishing.

If the mixture is composed simply of portland cement and clean, hard, durable stone of the right gradation, with only sufficient sand to make the mixture workable under a trowel, and is properly mixed, placed and finished, it will withstand extremely hard usage with a minimum of depreciation and repair. It is the most economical of all good surfaces.

The life of a good granolithic floor is probably greater than that of any other floor surface. A limit of twenty-five years is conservative, and replacement of worn sections will prolong the life of a floor indefinitely. Renewal is a simple matter involving cutting away the full thickness of the original surface course and, after careful cleaning and preparation of the base, replacing with the usual granolithic mixture in the ordinary way.

METHODS OF CONSTRUCTION

There are two common methods of applying a granolithic surface to concrete floors. The first of these is the integral method, by which the granolithic finish is applied to the structural slab before the slab has thoroughly set. The second is the bonded or "laid after" method, where the structural base is placed as one operation and the granolithic surface applied as an entirely separate operation, usually some weeks after the structural work is completed.

Integral finish, being practically part of the structural slab, has the advantage of giving absolute assurance of the surface adhering to the base. There are, however, certain disadvantages from a construction viewpoint, which are in most cases sufficient to make the use of the integral method inadvisable. The principal disadvantage is the possibility of damage to the floor itself. A newly placed granolithic surface cannot be used for at least five days and even then should be protected and must be carefully used. Accordingly, whenever the integral method is employed, construction is delayed until the new floor can be used as a working surface. It is practically impossible to keep the surface from being scratched or marred to some extent because the finish cannot attain a sufficient degree of hardness during the period for which it is practicable to hold up construction. The integral finished floor is likewise subject to damage from rain, hail or frost before it has set, since it is difficult to protect the exposed surface.

When the bonded or "laid after" method of finish is used, there is no delay to the progress of the structure, as the surface course is omitted and the structural slab is used as a working surface immediately after placing. The granolithic surface is scheduled to be laid at the most convenient time in the operation, usually after the roof is completed, the building closed in and all shoring and construction material removed. This method insures adequate protection to the new finish and offers an additional advantage in that any inequalities in the base course, caused by settlement of forms, etc., are taken care of when the finish is laid. There is no necessity for appreciable use of the finished floor for construction purposes and a better opportunity is allowed for the surface to properly harden before the floor is used.

The principal disadvantage in the use of the "laid after" method of placing granolithic is the possibility of imperfect bonding of the surface course to the structural base. Careful preparation of the base and thorough workmanship are essential to insure bonding. Imperfect bonding is more likely to occur in the case of stairs and other small areas and for this reason such areas are usually placed integral with the structural base. Good workmanship, however, effectively prevents trouble from this source in any area, large or small.

The method of construction, integral or bonded, may be readily decided upon after considering the advantages and disadvantages of each. Properly laid integral finish should cost approximately 10c per square foot as against approximately 14c for the bonded finish. The difference in cost is due principally to the necessity for cleaning and preparing the structural base before the bonded finish can be applied. This difference is, however, more than offset by the cost of protecting integral finish from damage and the saving made through quicker progress of the construction as a whole. In general, the advantages of bonded construction have won for it a preference over the integral method.

One of the commonest objections to a granolithic surface is dusting, or the rapid wearing away of the fine material. This condition may be caused by foreign elements in the aggregates, by improper proportioning of the component materials so that the surface contains too great a proportion of cement and fine aggregate, an improper consistency of mixture or by poor workmanship particularly over-troweling which tends to bring the fine material of the mixture to the surface. Because of the better wearing quality of stone, a mixture of 90% stone and 10% cement would be desirable if such a mixture were workable. It is, however, a practical impossibility to work a mixture of this proportion, and accordingly the percentage of stone is reduced and a minimum proportion of sand introduced. If the finish is mixed too dry the surface is porous and the aggregates not being well bonded, will work loose, producing a dusty condition. Finish mixed too wet allows excess water to rise to the surface, bringing up fine particles which wear away quickly. The use of dryers (sprinkling the surface with neat cement or cement and sand) renders the surface dusty because these particles do not bond well with the surface below.

A granolithic floor laid under wholly favorable conditions with the best of materials and workmanship will not of itself dust. That is, it will wear out so slowly that the amount of dust that accumulates is imperceptible. In some cases, however, even a well-laid floor will show a slightly dusty condition when first placed but will become dustless after a few months' use.

EFFECT OF GRANOLITHIC FLOORS ON OPERATIVES

The commonest objection to the use of the granolithic floor is that it is unsatisfactory to the plant operative and that it reduces his efficiency. The chief cause of this seems to be due, not to its hardness, but to its greater heat conductivity which makes it the last thing in the factory to warm up. Under certain conditions, it seems clear that this coldness of the granolithic floor has an unfavorable effect on the comfort and perhaps to some small degree on the health, of operatives who have to stand inactive for long periods, as in the case of tending a machine. To overcome this objection, wooden gratings, or small linoleum mats or trackers, are often provided though they are usually discarded by employes as being nuisances. In many cases the simple expedient of having employes wear thicker soled shoes has proved sufficient to banish complaints. Workmen who are continually moving around rarely object to the granolithic floor.

Unquestionably the attitude of employes toward the granolithic floor is oftentimes due to a preconceived notion, not supported by actual experience. As a typical case, a textile manufacturer installed some looms on a concrete floor and there was an immediate howl of protest on the part of the girl operators because the floors were so hard. Later an addition was built which had identical light, ventilation, etc., but was of wood, with wood floors. The girls all wanted to work on the wood floor, but, to the owner's surprise, soon wanted to get back to the concrete floor. On investigation it was found that the vibration of the wooden floor affected them so that they became very much more fatigued than when working on the concrete floor. This manufacturer is now thoroughly convinced that the concrete floor is superior for textile mills.

WEARING QUALITIES

Trucking is the commonest cause of excessive wear on granolithic floor surfaces. In corridors, aisles, etc., where most of the trucking goes on, ruts are often worn. This trouble is chiefly due to the use of truck wheels that have perfectly flat, square edged rims. Examination of such wheels shows that the edges are often nicked, proving that much of the weight and wear comes on the edge of the wheel rim. Such a wheel has all the effect of a cutting edge carrying considerable weight and even the hardest of floor materials cannot stand up under such continued abuse. If the rim edges of the wheel were rounded, the amount of wear would be greatly decreased since the cutting effect of the edge would be done away with. Another remedy is the use of soft-tired wheels, although factory executives have been slow to adopt these, partly from the bother of keeping soft-tired wheels in proper condition and partly because moving loads require more power than in the case of hard wheels. Wheels made with fibre tires are available, as are also wheels made with sheets of fibre bolted together as well as wooden wheels of various construction. A wheel made with hardwood cut into sectors with the grain radial, and with two or three thicknesses of this hardwood breaking joints, makes an entirely satisfactory wheel for heavy loads and is particularly effective on wet floors. Trucks equipped with wheels of this sort save repair costs and operate just as easily as a truck with metal wheels. They are a good investment.

USE OF STEEL AND IRON SURFACES

Where trucking is particularly severe, nothing but iron or steel will bear up under the cutting and pounding of the truck wheels. Cast iron plates and steel racks can be readily embedded in the granolithic finish before it has set. Steel plates are commonly made fifteen or eighteen inches square, with checkered surface and a flange which turns down around the edge of the plate. A hole is provided in the top to allow the air to escape during the setting. The cement bonds hard enough to the flange to hold the plate in place. It is a mistake to attach steel plates to the floor by bolts or rivets set around their edges, since the rolling of the truck wheels tends to expand the surface of the plates. If the attachment to the under flooring is made at the center of the plate, the effect will be to make the edges cling to the floor. A cheaper and equally satisfactory arrangement is the embedding of racks of small flat bars separated by thick washers and bolted together. They are set flush with the surface of the concrete and take the wear of the trucking satisfactorily.

Industrial tracks are often very advantageous for use in connection with granolithic floors, where material is moved in definite lines.

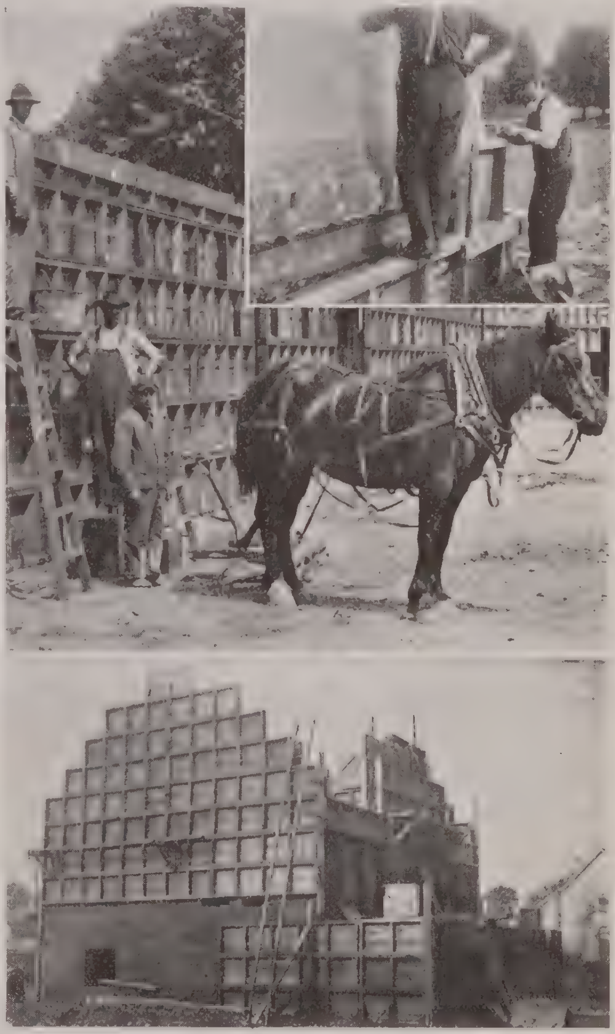
CONCLUSION

The successful granolithic floor is the outcome of good workmanship, carefully selected and properly proportioned materials, and continued protection against premature drying. Good, sound concrete that has the proper wearing and lasting qualities, laid with skill and care, produces a durable, dustless surface that is wholly satisfactory for most industrial purposes. A carelessly laid granolithic floor is a poor investment under any conditions.

Hutchins System of Form Panels

The pictures show the Hutchins form system as developed and used by Colin Hutchins in building houses and other structures in Leamington, Ontario.

Form panels are framed with 2x4's in 2-ft. widths, in 4, 6, 8, 10 and 12-ft. lengths. They are sheeted up on one side with $\frac{7}{8}$ lumber and covered with galvanized iron. They are secured in place with spikes slipped through holes in one unit and tapped into the adjacent unit and further by clamps as necessary. Spreaders are put in place and the inside and outside forms drawn together by wires. A collapsible core unit is made of sheet metal on an angle iron frame. This is 4 ft. deep in convenient lengths and is pulled up as the work progresses.



The Hutchins form system in use

With four to six men and a horse which drags the "boat" of wet mixed concrete from the mixer the walls of a cottage can be carried up 4 to 6 ft. a day of eight hours. A small detail shows a basement window frame in place and the coves to provide spaces for joists. After the excavation is made and the footings ready the forms are rapidly set up.

Mr. Hutchins is building very successfully and economically with his own forms, which are patented, in Leamington and vicinity.

Australian Concrete Cottage

Concrete houses with walls as shown in the accompanying illustrations are built on a system patented by A. C. Mathews, an Australian architect and engineer, and the outstanding features claimed for this method are the following: An average saving of from $500 to $750 as compared with an ordinary brick dwelling; the average time to erect the walls of a 5-room house with 5 men is 4 days; men may easily be found to make the segments; perfect insulation from external temperatures and dampness; weight of walls is one-third of brick walls.

The walls are built of concrete slabs with end and intermediate ribs which when assembled form vertical enclosures at the ends of certain slabs and at the middle of opposite slabs. Within the enclosures formed at the ends of the slabs, concrete is poured to form columns.

The details of the system and the method of operating it are shown in the accompanying illustrations from *Concrete and Constructional Engineering*.

The method of molding the slab so that the projecting ends of the anchor portions of the reinforcement are prevented from adhering to the plastic material is shown as is also the method of uniting the projecting anchor portions of the reinforcement of opposite slabs in the solid column. Alternative methods of obtaining the same results are also shown.

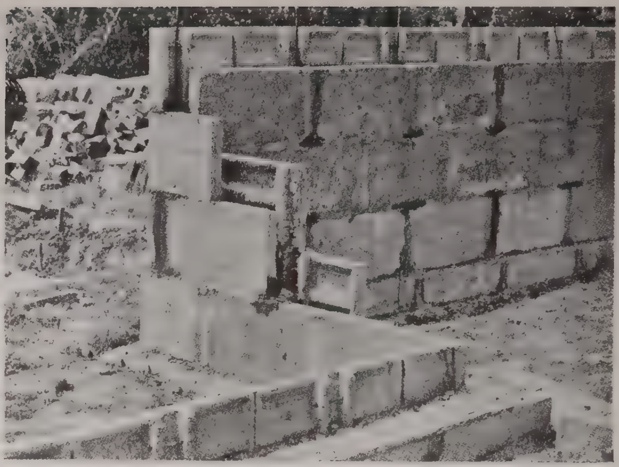
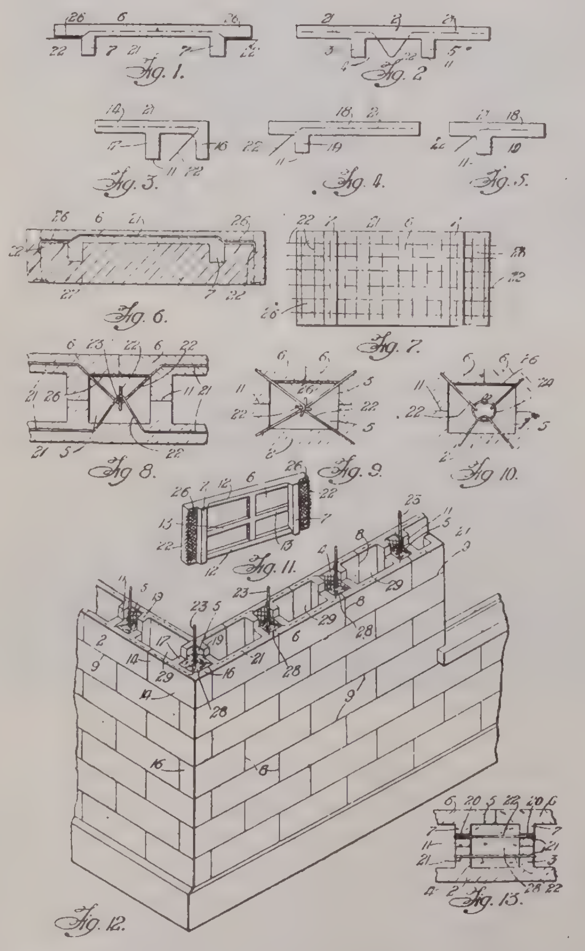


Fig. 14—Wall partly built in the Australian method of concrete block construction

Certain slabs are provided with an intermediate pair of integral ribs which project from one side of the slab near its middle and extend vertically.



Figs. 1-13—Details of units and methods of combining them in the wall

The vertical joints between the ends of adjoining slabs, forming the inner section of a double wall, are staggered so that moisture cannot pass directly through the vertical joints of the inner and outer wall sections. The horizontal joints of the inner and outer sections of the wall are disposed out of alignment with each other by inserting at the bottom of one section, slabs of half the height of the bottom slabs.

Each slab has embedded within it a metal reinforcement provided with projecting ends or anchor portions. In the case of the intermediately ribbed slabs, these projecting anchor portions protrude into the vertical channel between the intermediate ribs. The anchor portion of the reinforcement may be fastened together in any suitable manner, a convenient means consisting in disposing vertical reinforcing rods or wires within the vertical enclosures and twisting or passing the anchor portions around vertical rods, as shown in the diagrams.

When a series of slabs has been assembled to form a double wall and with the ends of the ribs of opposite slabs abutting, as in Figs. 8, 9, 10 and 12, a series of vertical enclosures of substantially rectangular cross section are formed between the slabs of the inner and outer wall sections. These enclosures divide the air space between the inner and outer wall sections into a series of compartments. The projecting anchor portions of the reinforcement are then fastened together by passing them around the vertical rods or wires or by other suitable means within the enclosures, so that the series of slabs are held together prior to pouring in of the material to form the vertical columns.

Stucco Finishes

A Guide to Good Stucco and Textural Finishes is a new publication of the Atlas Portland Cement Co., 25 Broadway, New York City; 32 pages, self-cover, printed on a high quality of paper with attractive and informing illustrations, both from photographs and from detailed drawings. It tells just how and why the best stucco work is to be done in a way that should appeal to the painstaking and discriminating architect, and at the same time make it easy for him to pass the work along to the contractor who is doing work under his direction. The booklet reproduces several of the theories of how-to-do-it photographs which CONCRETE published through the courtesy of the Atlas Portland Cement Co., in its October and November issues, showing just what motions are gone through by the workman in applying stucco in the various textural finishes.

The American Concrete Institute Convention

(Continued from page 83)

Concrete Products Manufacture

Committee P-6, on Concrete Products Plant Operation, observed the operation of concrete products plants throughout the year with a view to (1) investigating and studying the effect of steam curing, (2) the practical application of quality control methods in the plant in making good concrete products, and (3) desirability of a recommended practice for making concrete block, brick and tile.

That part of the committee's report covering "Recommended Practice" is more concise than the previous A. C. I. standard. The first section states standard requirements and storage room specifications for cement. Under the heading, "Aggregate" the general definition is given and the diameter of the largest particle is limited to a size not greater than one half of the thickness of the thinnest wall of the concrete building unit in which it is used. The aggregate is to be of good structural quality and should not have more than 10% by volume of very fine material. Notes on general plant arrangement and the handling of products are included.

Water should be free from harmful material, or in general should be fit for drinking purposes. The heating of the water during cold weather operation is recommended because of its effect in hastening early hardening.

Only mineral pigments are to be used for coloring.

The proportions of cement to aggregate are specified as such that the products will conform in strength and absorption to the current requirements of the American Concrete Institute for such products or conform to any state or municipal building code under whose jurisdiction the products are used.

The consistency of the concrete should be so regulated that tamped products are mixed as wet as practicable, allowing immediate removal from the mold without sagging or distortion and cast products should be made as dry as practicable to completely fill the molds and produce acceptable surfaces.

Mixing aggregates dry until a homogeneous mass is obtained and further mixing for at least two minutes after the water is added is specified.

Under the heading "Admixtures," the use of calcium chloride is mentioned, quantities of not more than 3% by weight of the cement increasing the strength of the concrete during the early hardening period and permitting more frequent use of molds and pallets.

* * *

Concrete from the Viewpoint of Mr. Cement

A paper by Thaddeus Merriman, chief engineer, Board of Water Supply, City of New York, tells in simple language something about cement and concrete of which cement is the basis. Mr. Merriman's paper gives much information as to the uses and abuses of cement in concrete construction and will be abstracted in a later issue.

* * *

Notes on Construction of Concrete Stadium

The following abstract of a paper by Dr. W. K. Hatt, Head of the School of Engineering, Purdue University, has particular reference to the construction of the Ross-Ade Stadium at Purdue.

A concrete stadium was constructed at Purdue University during the summer of 1924. The materials entering into the concrete were excellent, the workmanship represents somewhat above the average of local concrete, the mixer was 2-bag capacity, without time-lock or automatic water control. The operator of the mixer had had 18 years experience. The concrete was mixed 1:2:3; aggregates, torpedo sand and pebbles from ¼ in. to 1 in. Speed cement was used. The daily average of slump varied from 3 in. to 8 in., probably averaging 6¼ in. The paper indicates the strength of the concrete as determined by the conditions of manufacture.

Cylinders were made at intervals from the beginning to the completion of the job; some exposed on the job and some cured in damp sand.

To arouse the workmen and foremen to the necessity of care, photographs were shown of several stadia in which defects had appeared, and of one stadium which had entirely failed.

The results of the 7-day and 28-day tests were communicated to these men as soon as the strength was determined. Insistence was placed on as dry concrete as was practicable. As the work went along the strength of the 7-day concrete was raised from 1500 lbs. per sq. in. to 2700 lbs. per sq. in., the cone slump being 7 in. and 3 in. respectively.

As the chief football game of the year approached when the stadium was to be ready for operation, the concrete became more fluid, slump increasing to 8 in. and the strength decreasing to 1400. A chart indicates the variation of the quality of the concrete under the circumstances of the work and the weather.

A number of gage lengths were set in various parts of the stadium and observations are being continued on the movements of the concrete. Air temperatures and concrete temperatures are read. The temperature and moisture movements are observed in a thin parapet wall, in an open reinforced deck, and in the seating slab which rests directly on a clay bank. Values of expansion and contraction are recorded. Movements so far correspond to a thermal coefficient of .0000050 for 1° F. and a unit swelling due to moisture of .00005.

* * *

Crazing

This paper by P. H. Bates, U. S. Bureau of Standards, chairman of the newly organized committee T-1 for the study of crazing in its many manifestations in concrete is published in full elsewhere in this issue.

In the discussion of crazing Thaddeus Merriman related an interesting experience with its elimination by washing the cement. The cement was flooded and stirred and the excess water poured off carrying the flour.

* * *

Shall Anything Be Added to Portland Cement?

A paper by Maximilian Toch of Toch Bros., New York City, dealing with colors, waterproofing and other admixtures for concrete is abstracted at length elsewhere in this issue.

* * *

Proportioning Concrete Materials, with Special Reference to Highway Construction

The following is a brief abstract of a paper by G. W. Hutchinson formerly of the North Carolina State Highway Department.

Based upon data available, it appears logical and economic to depart from the universal application of single theory for proportioning of concrete for all purposes. The data given bear directly on the design of concrete mixtures for highway construction and greater economy may be secured by considering the type of structure when designing the concrete mixture. The use of data which appear to be more or less contradictory to present tendency or practice with reference to either building or highway work should be given serious consideration, especially with the growing tendency to use the larger sizes of coarse aggregate and because of the great amount of segregation taking place during the handling of cars to storage piles.

In building construction, the period of time which must elapse before the concrete is called upon to withstand loads nearing the ultimate is earlier than in highway construction and it is logical to assume that the highest ultimate strength with consistent early strength is the principal feature to be considered in the design of concrete mixtures in highway construction.

The paper brings out a new method for proportioning concrete materials and the data derived from it given in summarized form.

The tests include practically every gradation of coarse aggregate used in normal concrete work. They also furnish data on the effect of variation in the cement content as well as in the ratio of fine to coarse aggregate. From the results secured, and by reasonable interpretation of the curves, etc., as indicated by definite tendencies, which in many cases are of as much importance as the curves themselves, the following conclusions are offered:

(*1*) *Concrete should be proportioned.*
  - (a) With a definite amount of cement per volume of completed mixture.
  - (b) By combining definite amounts of several definite sizes of aggregate.
  - (c) With reference to a desired strength at a given age.
  - (d) By regulation of either the amount of cement, the size and type of the aggregate, the ratio of fine to coarse aggregate, or combinations of these, to secure the desired quality under "c" economically.
  - (e) All tests for comparison or determination of quality should be made from concretes of equal volumes and consistencies.

(*2*) *With all other factors equal*
  - (a) The compressive strength and the resistance to impact of concrete are increased as the size of the coarse aggregate of decreased. The minimum limits appear to be governed by the amount and quality of cement in the mix.
  - (b) The relative increase in compressive strength of the oversanded mixtures, while higher at the early period (28 days), is lower at later ages (or other normal factors causing increased actual strength).
  - (c) This effect (b) is greater as the size of the coarse aggregate is decreased.
  - (d) The relative compressive strength of concretes containing the smaller sizes of coarse aggregate increases at a greater rate than those containing the larger sizes.
  - (e) The relative compressive strength of concretes having lower cement contents increases at a greater rate than those having a higher cement content.

(*3*) *There is an economic relation between the amount of cement in the mixture and the maximum size of the coarse aggregate used.*

(*4*) *Age or other causes whereby the strength of the concrete is normally increased, affects changes in the relative strength of concrete mixtures.*

(*5*) *Tests at the early ages (7 and 28 days) are suited only to determine the quality of concrete at such ages. They do not truly indicate the proper relation between different mixtures at the later ages. In the leaner mixtures, they have a tendency to be more misleading than in the richer.*

(*6*) *In normal concrete mixtures, there appears to be a definite relation between the resistance to impact and the compressive strength.*

(*7*) *The quality of the coarse aggregate affects both the compressive strength and the resistance to impact of concrete.*

(*8*) *With different types of coarse aggregates, size may be adjusted to compensate for difference in quality of concretes having equal cement contents. Cement may also be used as a means to accomplish the same purpose.*

(*9*) *The effect of change in relative strength on the actual strength of concrete, containing various amounts of cement, gradations, and types of aggregates, etc., should be considered especially in the design of concrete mixtures for highway construction.*

(*10*) *By making tests of various types of aggregates in concretes rich in cement, it is possible to approximate the relative values they will possess in the more normal mixtures at the later periods. The smaller size of aggregate (⅜ in.-¾ in.) should be used for this work.*

Expansion Tests on Gunite

Discussion of the coefficient of expansion of Gunite as compared with that of concrete resulted in tests being performed at the Fritz Engineering Laboratory, Lehigh University, Bethlehem, Pa. As far as it is known, these were the first tests ever conducted to determine the coefficient of expansion on Gunite. They are described in a paper by Prof. M. O. Fuller. The specimens used in making the determinations were rectangular pieces 8 in. x 12 in. x 1¼ in. which had been cut from a Gunite slab.

The following table gives the results obtained on five specimens of Gunite:

Specimen No.	Original Length, inches	Room Temperature degrees F.	Highest Temperature Recorded, degrees F.	Difference in Temperature	Mean of Two Telescopic Readings, inches	Coefficient of Expansion per degree F. for Temperature Given
1....	6.05	57	1098	1041	0.04120	0.00000654
2....	5.53	60	970	910	0.03220	0.00000644
3....	5.32	60	1234	1174	0.04020	0.00000643
4....	6.03	60	1198	1138	0.04390	0.00000641
5....	5.83	60	1297	1237	0.04637	0.00000643

* * *

Road and Street Standard Specifications

The tentative standard specifications for two-course concrete pavement for highways, for one-course concrete pavement for streets and for two-course concrete pavement for streets as presented by Committee S-6 were accepted to be submitted to letter ballot for adoption as standards with an amendment in an editorial note referring to paragraph II-B on aggregates, omitting the sentence relative to the Abrams tables for proportions and quantities of concrete. The paragraph referring to coarse aggregate was revised by omitting an inadvertent reference to blast furnace slag, which while acceptable as an aggregate was eliminated in the original draft by a wear test requirement.

* * *

Inundation Method to Control Moisture Content

A paper was presented by A. A. Levision, chief engineer, road department, Blaw-Knox Co., Pittsburgh, Pa., descriptive of equipment designed for the adaptation of the inundation method for measuring sand for concrete. Different installations where inundators were used were illustrated, and the principles upon which the inundation method is based were discussed.

* * *

Pipe and Drain Tile

Committee P-7 on Concrete Pipe, Drain Tile and Conduit recommended that the Tentative Standard Specifications for concrete drain tile be submitted to letter ballot of the Institute to become a standard; that the proposed Standard Specifications for plain concrete drain tile of 1910 and 1911 and that the recommended practice for plain concrete drain tile of 1912 and the Standard Specifications for concrete drain tile of 1917 be withdrawn. The committee further recommended that the Tentative Standard Specifications for plain concrete sewer pipe be continued as tentative standard for another year and that seven amendments be made to the Tentative Standard Specifications for reinforced concrete sewer pipe. These amendments provide one strength of reinforced pipe for sewage conveyance; define fine and coarse aggregates used in pipe; define mixture; provide for two types of pipe including field-made cast concrete pipe and shop-made mechanically compacted pipe; change the specified per cent of steel reinforcement.

Notes on Finishing Concrete Floors

Four points are made by E. E. Davis in his paper, with regard to the construction of concrete floors as follows: First, that the floors in a building structure are a real asset to the value of the property; second, there is a great tendency on the part of all concerned to put in floors just as cheaply as possible without regard to their lasting quality and with little, if any, regard for the branch of the industry in which all are interested; third, that in the consideration of floors, only the ordinary precaution of proper selections of aggregates, correct mixing, sufficient curing and conscientious finishing are necessary to obtain an acceptable job; fourth, that no kind of after treatment will compensate for a poor job.

Floors may be divided into approximately 18 different groups based on the physical property of the floor which classifies it as an acid resistant floor, an alkali resistant floor, as a thermal insulator, as a fire resistant medium, etc.

There are three main materials, namely, cement, aggregate and water that go to make up a concrete floor. The cement used should meet the current standard specifications for portland cement adopted by the American Society for Testing Materials. A safe rule for mixing water for concrete is to use only that which is suitable to drink and is therefore clean, free from oil, acid, alkali and foreign matter. As it is the aggregate that must resist the wear, that part of the floor mixture must be carefully selected. There is a very wide range in the quality of aggregate. As the sand or fine aggregate varies around the country, the mixture of concrete and the method of mixing have to be changed materially to meet the governing conditions.

Having selected the cement, water and aggregate, the next important subject is to determine the mix to be used. This necessarily depends upon the size and nature of the aggregate. The proper mixture to use can be determined from the results of a sieve analysis. Experiments in first thoroughly mixing the water and the cement and then depositing the aggregate slowly so as to thoroughly hydrate the cement before it comes in contact with the sand and stone, indicate that each particle of cement will function as intended.

Excess water should be avoided as an excess results in voids, and minute hair cracks which later contribute to the early disintegration of the floor. After the finish has been deposited on the structural floor slab, it should be compacted by rolling, floating and troweling. The troweling should be done after the floor has dried to the proper consistency but before the floor gets too hard. This treatment produces a smooth, glossy surface. Good smooth surfaces can be obtained with the use of a rotary machine equipped with carborundum stone, a coarse grade of stone being used for the preliminary grinding and a finer stone for polishing the surface.

In applying a wearing surface to a concrete floor, the topping can be mixed with the least amount of water possible and applied on the structural slab shortly after it has been poured or it may be applied later after the concrete has set and hardened. Another method is the application of a dry mixture of cement and aggregate deposited on the structural slab as soon as it is leveled off and while it is still very wet. The water in the concrete is depended upon to mix with the dry mixture to hydrate the cement. The thickness of this dry mixture depends necessarily upon the consistency of the concrete to which it is applied.

The matter of air circulation is of considerable importance. In outside work, no provision need be made for circulation but for inside work, this must be taken into consideration.

In many cases, buildings or certain sections of them are used for the manufacture or storage of chemicals, acids or other materials having injurious effect upon the concrete and unless some special treatment is given by the application of some liquid or preparation, failure will result. In connection with the use of coloring matter with cement in concrete the services of a chemist should be enlisted to insure the combining of colors with cement in water in such a way that the wearing qualities and strength of the cement will not be affected.

* * *

Floors and Sidewalks

Standard specifications for portland cement concrete sidewalks were presented by committee C-2 on concrete floors. These specifications have been tentative standard for 1 year and were passed to letter ballot to be voted on as standard.

* * *

Central Mixing Plants

W. E. Hart, manager Structural Bureau, Portland Cement Association, pointed out possibilities in the sale of ready mixed concrete by material dealers. The establishment of central mixing plants for the production of ready mixed concrete was suggested by the successful operation of similar plants in concrete highway paving, and the operation of these central plants on large construction jobs, brought out a number of advantages which factory production has over hand work and which large production plants have over small temporary field plants.

The following conclusion sketches some of the advantages and disadvantages of the central mixing plant.

One of the principal advantages is the fact that it places the mixing of the concrete in the hands of one man where materials can be graded, proportioned and mixed much more uniformly than in the field. Manual labor is reduced and machinery substituted for it. The expense of moving contractor's equipment from place to place is eliminated and at the same time storage space for materials is eliminated on the job. Perhaps the great disadvantage is the fact that only the stiffer mixes can be transported. Establishing central mixing plants assures reducing very materially the water content in all concrete.

The principal limitation of the central mixing plant is one of transportation. Only the stiffer consistencies can be delivered successfully by truck without segregation and settlement into the body of the truck. Other difficulties to be covercome include the transportation of concrete into congested areas and the necessity of avoiding delays in the arrival of these materials at a large construction job. Prejudice will be encountered on the part of the contractors due to the fact that they already have expensive equipment on hand which cannot be discarded due to the character of their business. Officials may not be entirely in sympathy with the laboratory tests and for that reason will rule out the use of centrally mixed concrete, fearing that the ultimate strength of such concrete will be impaired by transportation. This is not considered an important point, as mixed concrete has been transported by a number of means for quite a number of years with good results.

Generally speaking, a central mixing plant is entirely practical and safe, provided it is in the hands of competent men.

Two fundamental points should be kept in mind with respect to the operation of central mixing plants—one pertains to cold weather operation. The concrete should be warm when delivered. The other point, which is of equal importance, applies at all temperatures—no water should ever be used in remixing concrete after it is delivered on the job.

* * *

Texture for Portland Cement Stucco

The story of how several of the more popular finishes for portland cement stucco are obtained was told with the aid of motion pictures by Samuel Warren, manager Atlas White

Department, Atlas Portland Cement Co., New York City. The actual operations by the workmen necessary in producing some of the most popular textural finishes with portland cement stucco and views of the very interesting results obtained were shown.

Professor Alphonse Eianelli of the Chicago Art Institute, in speaking of the application of stuccos to the styles of various periods of architecture, suggested that the architect should have a guide in obtaining textures corresponding to the periods the designs of which they are using. Craftsmen must be in sympathy with the material they use. Architects in Europe consider the construction work in American concrete as their ideal and as the structures are available for study representing the various periods of architecture, interesting and important results are to be expected.

* * *

Treatment of Concrete Surfaces

J. C. Pearson, Chairman Committee C-3, on the Treatment of Concrete Surfaces, reported progress on tentative standards for the treatment of exterior surfaces of industrial concrete buildings in which have been embodied portions of an old Institute standard on scrubbed concrete surfaces.

Progress was also reported toward tentative standards for interior finishes, including plastering. Specifications for each coat are given, including formulae. The conclusion of the report contains recommendations for further study.

An interesting point was mentioned in connection with portland cement plaster, to the effect that where more than one coat is applied each successive coat should be leaner than the one to which it is applied.

* * *

Dwelling Houses

The report of Committee S-5 presented in abstract from a preprinted report by J. A. Ferguson, chairman. The committee stated that its report needed criticism and suggestions from Institute members. It is the Committee's intention to submit next year data showing the present state of the art in the use of concrete and reinforced concrete for dwelling houses. It is anticipated that during the next year there will be prepared a final section to include a program for requirements under which detailed standards may be prepared for individual systems and forms of construction, adaptable to concrete house construction.

The recommended practice is divided under the following headings: materials; design; construction; and hollow or solid concrete block or tile for masonry piers and load bearing and exterior walls.

The committee reports that certain facts of common knowledge in regard to the strength of concrete as compared with well-known types of lighter construction should be given expression in regulations for the concrete type, and the committee on general design is being relied upon in the study of design as applied to concrete houses.

* * *

Concrete Masonry Units

The Tentative Standard Specifications for Concrete Building Block and Concrete Building Tile and for Concrete Brick (*Proceedings* A. C. I., Vol. 20, 1924) were recommended for advancement to standards with an editorial note to clarify one part relative to the testing of units. It was the intent in preparing the tentative standards that specimens should be tested in a dry condition and the editorial note recommended by Committee P-1 was provided in order to make that point more definite.

Fire Resistance of Concrete Building Units

Committee P-5 on the Fire Resistance of Concrete Building Units reported that the work assigned to it has been completed. The final report contains a summary of the conclusion of the report of the Underwriters' Laboratories. The Laboratory has definitely assigned to units of the character tested a fire-resistance rating of 2 hours. Tests of concrete units were concentrated on the types most generally used because finances were not available for complete tests. These first tests, the committee hoped, might be recognized as a basis for further tests.

Several important conclusions as drawn by the Underwriters' Laboratory from the observations made during the test are referred to by the committee. Details of the test were given in the *Proceedings* of the American Concrete Institute Vols. 19 and 20.

The committee reports that this series of tests has laid a foundation for a series of investigations which could very properly cover the field of all masonry units used in wall assembly, and it may also prove a starting point for an intelligent system of inspection which will eventually extend to all mason's materials. The committee believes it is noteworthy that this is the first instance of an industry producing mason's units, that has carried out at its own expense, a comprehensive series of tests and published the results. The tests would be of far greater value to the building industry if other industries producing mason's materials were also to institute similar test programs in order that an exact comparison of fire resistance might be made.

* * *

Concrete Products Plant Operation

Committee P-6, of which John Lowell is chairman, presented a simple recommended practice for concrete masonry unit manufacture to help manufacturers make products, including building block, building tile and brick to meet the requirements of the standard specifications of the American Concrete Institute. This recommended practice will appear in the *Proceedings*, Vol. 21, 1925, as a tentative standard. This report of Committee P-6 was given detailed, informal consideration during the sectional meeting of concrete products manufacturers, Wednesday afternoon, February 25.

* * *

Measurement of and Estimating Concrete

The report of Committee C-5 giving rules for the measurement of and estimating of concrete, founded upon an early Institute standard, was adopted as a tentative standard with an amendment to rule 23 relative to the measurement of beam and floor forms. The amendment provides that the form area for the breadth of the beam shall be deducted from the total area of the floor form and not included with the floor form as originally provided in rule 23. The report will appear in full in the Institute *Proceedings*, Vol. 21, 1925.

* * *

Reinforced Concrete Chimneys

Committee S-1 presented a preliminary report on Recommended Practice for the Design of Reinforced Concrete Chimneys and a proposed Tentative Standard Specification for the Construction of Reinforced Concrete Chimneys. The preliminary report on recommended practice was offered as a progress report with the expectation that the committee will present to the next convention of the Institute a more complete report on the design of reinforced concrete chimneys.

Further data upon which to base definite formulae for the design of reinforcement to resist temperature stresses are expected as the result of some tests which have been under way for some time, bearing on the relative temperatures at various points in the thickness of the wall of concrete chimneys.

Relative to the Proposed Tentative Standard Specifications for the Construction of Reinforced Concrete Chimneys, it was voted on the floor of the convention to refer the proposed tentative standard specifications back to the committee for further study on the ground that they were not complete enough to represent the ideas of the Institute as a whole.

* * *

Temperatures in Reinforced Concrete Chimney Shells

E. A. Dockstader, Stone & Webster, Inc., Boston, presented a very interesting paper describing some tests made to determine the temperatures in the shells of reinforced concrete chimneys based upon research work by Stone & Webster, in the last year.

* * *

Fire Resistance of Concrete

Committee E-4 on fire resistance of concrete, which has had under consideration the question as to what, if any, action should be taken on the matter of adoption of the 1918 proposed standard specifications for fire tests of materials and constructions recommended that no action be taken to accept the 1918 report.

A resume based upon the findings of the committee after a study of test data and of fires will be presented in a later issue of CONCRETE.

* * *

Expansion Joints

The report of Committee E-8 on expansion joints in concrete construction was not read on the floor of the convention except by title. Seven additional expansion joint details have been presented by the committee to be appended to its 1924 report to constitute a final report.

* * *

Design of Reinforced Concrete Circular Bins for Storage of Cement

This paper by H. A. Ward, engineer, Turner Construction Co., Buffalo, N. Y., is of interest to concrete designers and is also of particular interest to manufacturers of cement where deep bin storage is largely used for the finished product. The paper considers general assumptions, action of cement in bins and pressures exerted, design of circular bin walls, design of bin floor slabs and design of foundations.

Coroner's Jury Recommends Metal Lath Construction

Following the death of seven as the result of an apartment-house fire in Chicago, January 31, a coroner's jury which investigated the deaths, is heading this appeal for building code revision by incorporating in their report a recommendation to the City Council that in every apartment building three or more stories high where the stairways are now plastered with ordinary lath these stairs be protected on all sides by metal lath and plaster. This type of construction was recently given a one-hour rating by the National Board of Underwriters. Had the stairs in the burned building been so protected, there would have been ample time for all the occupants to escape safely. Death came to two people who, finding the stairs on fire and their means of escape cut off, jumped from the upper windows.

"In view of the apparent rapid progress of the fire caused, in our opinion by the main stairways being enclosed in common wood joists and covered with wood lath and plaster, the stairways also being constructed of wood, and other combustible material, which type of building construction would not be permitted under present building ordinances of the City of Chicago, and to our knowledge, there are now in existence many buildings three stories high of practically the same type of interior construction, we strongly recommend that ordinances be passed by the City of Chicago, declaring all buildings of similar type of construction having three or more floors above the side walk level to be subject to condemnation unless the owners of such buildings remove all lath and plaster from either side of the wood studding enclosing all vertical openings, said studding to be covered on both sides from the basement to the roof with metal lath, and covered with cement plaster."

The apartment building in which the fire occurred was about 30 years old, and was originally intended for eight families. Several years ago, the inducement of high rent caused the owner to subdivide the building into apartments by the simple process of closing communicating doors and renting out two or three rooms to a family. Although under the new plan the building housed four times as many people as formerly, no additional safeguards were provided. After the fire the halls were found to be filled with net works of exposed electric wires and tenants say that the halls and stairways were constantly littered with piles of waste paper and other rubbish. The building had not been inspected since 1920.

Firemen who testified at the inquest said that this building was no different from hundreds of buildings in Chicago and which might catch fire at any time with similar disastrous results.

Lateral Strength of Cinder Block and Brick Walls

The Harrisburg Building Block Co., manufacturers of Straub cinder concrete block, had tests made of a rather unusual nature.

Two wall sections on panels slightly under 7 ft. long and 32 in. high, one of clay brick and the other of cinder block were laid horizontally and were loaded to failure. This test, made November 7, 1924, was reported under date of January 19, 1925, by E. L. Conwell & Co., Engineers, 2024 Arch street, Philadelphia, Pa.

The walls were erected by F. J. Straub, a practical bricklayer, October 29, 1924, and were laid up in lime mortar. These walls were inspected by our representative in both vertical and horizontal positions before the test and found to be of good standard workmanship.

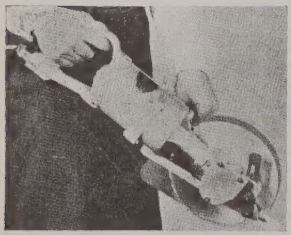
Specimens were supported flatwise on 4 ft. centers and loaded at the center point with cinder block until failure took place. The brick wall specimen failed under a load of 379 lbs. The Straub block wall specimen failed under a load of 1227 lbs.

The illustration shows the cinder block wall specimen sustaining a load of 1000 lbs.

Show Home in Process of Construction

The Chicago "Own Your Home" show will be held at the Coliseum March 21 to 28. This year the various exhibit committees, particularly the Architectural and Building Materials Committees, have decided to go further, and show the right way to build a home. and the proper uses of certain materials, and that builders and contractors will find it to their interest to observe these methods as will be demonstrated in a novel way at the Chicago and New York expositions. There will be erected in the center of the floor, a vine covered facade, with an English rose garden, a portion of the roof and several windows to demonstrate the various modern types of windows and frames. This front elevation will be complete in every way and give the appearance of a finished house, and the rest of this structure will be shown under the process of construction, showing how a foundation should be laid, walls built, and plumbing installed. Partly constructed walls, cross section displays, exposed plumbing fixture connections, a strip of flooring adjoining one of the partly constructed walls (showing how floors should be laid), various types of insulating material exposed in side walls and other products will be on view.

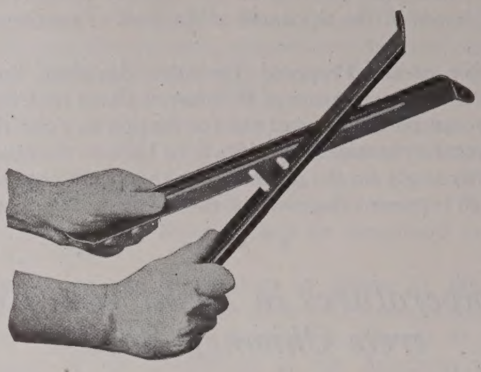
Portable Electric Circular Saw



Skilsaw is a portable electric circular saw. The body is of aluminum with self-contained motor and the saw is 8 in. in diameter and is hooked up for use with an ordinary extension cord. It is made by the Michel Electric Hand Saw Company, 166 East Grand Avenue, Chicago. The equipment is shown in the accompanying illustration. It has had a good deal of use in cutting up lumber for form work in concrete building construction.

Steel Bridging

A new device to save time, labor and expense in construction is the new GF Duplex steel bridging marketed by the General Fireproofing Co., Youngstown, Ohio. Cutting, fitting and nailing in cross bridging has always been a slow and puttering job. Each piece of the new steel bridging is a complete cross bridging of standard size installed in a small fraction of the time required to cut and nail wood bridging. The bridging comes finished, ready to nail in place. Each unit is made of a single piece of steel cut and formed to accurate shape and size making a complete cross bridging. Nailing ends are bent to the proper angle and all that is necessary is to spread the two arms of the bridging apart by hand and nail to the joist. GF Duplex steel bridging is made from heavy gauge steel, flanged and ribbed to give extra stiffness and then painted. It requires only four nails as against eight for wood bridging, and because it is all in one piece it is handier to use and can be placed in position in less time.



Organizations

American Concrete Institute; Harvey Whipple, Secretary, 1807 East Grand Boulevard, Detroit.

American Concrete Pipe Association; M. W. Loving, Secretary, 111 West Washington St., Chicago.

American Engineering Standards Committee; Dr. P. G. Agne, Secretary, 29 W. Thirty-ninth Street, New York City.

Associated General Contractors of America; G. W. Buchholz, Secretary, 1038 Munsey Bldg., Washington, D. C.

Associated Metal Lath Manufacturers; 123 W. Madison St., Chicago; Wharton Clay, Commissioner.

Building Officials Conference; Rudolph P. Miller, President, Fred W. Lumis, City Hall, Springfield, Mass., Secretary.

Iowa Cement Stave Silo Association; H. E. Kilmer, Secretary, Oskaloosa, Ia.

Iowa Concrete Products Association; Ross Dowell, Secretary, 405 Hubbell Bldg., Des Moines.

Mid-West Concrete Products Association; D. R. Donlen, Secretary-Treasurer, 4340 Marcy St., Omaha, Neb.

National Association of Manufacturers; John E. Edgerton, President; Henry Abbott, Treasurer; George S. Boudinot, Secretary, 50 Church St., New York City.

Ohio Concrete Products Association; G. M. Friel, Secretary-Treasurer, 2284 North High Street, Columbus, Ohio.

National Crushed Stone Association; A. P. Sandles, Secretary, 405 Hartman Bldg., Columbus, Ohio.

National Housing Association; Lawrence Veiller, Secretary and Director, 105 East 22nd St., New York City.

The National Lime Association; Mather Bldg., Washington, D. C.

National Sand and Gravel Producers' Association; T. R. Borrows, Acting Secretary, 903 Munsey Bldg., Washington, D. C.

Portland Cement Association; William M. Kinney, General Manager, 111 West Washington Street, Chicago.

Wisconsin Concrete Products Association; D. R. Collins, Secretary-Treasurer, Milwaukee.